



REPORT OF WATER QUALITY IN HARP LAKE DISTRICT OF MUSKOKA

1973



Ontario

Ministry
of the
Environment

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Minister

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Deputy Minister

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REPORT
OF
WATER QUALITY - REG - CAN - ONT - SOUTH CENTRAL
IN
HARP LAKE
DISTRICT OF MUSKOKA
1973

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PREFACE

The Province of Ontario contains many thousands of beautiful small inland lakes which are most attractive for recreational use. Lakes close to urban areas and accessible by road often receive heavy use in terms of cottage development, camp sites, trailer parks and picnic areas.

A heavy influx of people may subject a lake and its surrounding environment to great stress. In some cases, developments are carried out on attractive lakes only to find that when this is complete the lake qualities which were initially so appealing have been damaged. The appearance of the shoreline can be marred by construction, fishing ruined by over-harvesting or by the growth and decay of excessive amounts of algae and weeds. Motor boats introduce noise and petroleum pollution. Inadequate disposal of human wastes can place a great stress on the lake environment.

The accepted custom of having "a place at the lake" continues to apply pressure for more development, giving rise to an even greater expansion of problems.

The Ontario Ministry of the Environment is attempting to bring some of these stress factors under control with a variety of programs. The cottage pollution control program was initiated in 1967 and was expanded in 1970 in order to solve the cottage waste disposal problem in recreational lakes. There are three on-going studies carried out by the Ministry:

1. Evaluation of existing waste disposal systems and enforcement repairs to those found to be unsatisfactory;
2. Research to improve the knowledge of septic tank operation and effects in shallow soil areas and evaluation of alternative methods of private waste disposal;
3. Evaluation of present water quality in a number of recreational lakes. A totally undeveloped lake near Huntsville was studied in 1972 and 1973 in order to obtain more information about natural water quality conditions within a Precambrian Lake, which would assist in defining any unnatural conditions encountered in the developed lakes surveyed.

This report on Harp Lake is one of a series describing the water quality of the recreational lakes studies in 1973. In view of very similar morphometry and drainage basin features characterizing the nearby undeveloped lake studied in detail in 1972 and 1973, comparable detailed studies (beyond the terms of reference of the regular Recreational Lakes Programme) were carried out on Harp Lake in 1973. As well as defining the present status of water quality in the lake, the data are meant to provide an historical reference for comparison of conditions at any future time.

SUMMARY

Surveys were carried out on Harp Lake in 1973 to evaluate the present status of water quality with respect to distributions and densities of bacteria, suspended algae (chlorophyll a) and aquatic plants. Additionally, plant nutrients, mineral constituents, temperature, and dissolved oxygen were determined throughout the lake during the ice-free period.

Harp Lake is located in Chaffey Township, District Municipality of Muskoka on Ontario's Pre-Cambrian Shield and has a surface area of 0.7 km² (180 acres), and a maximum of 36 m (118 feet). The surrounding area is characterized by rugged forested terrain, with shallow overburden covering bedrock.

In May, July and September the bacteriological water quality of Harp Lake in 1973 was generally very good, and with the exception of the mouth of the four inflowing streams, was within the Ministry of the Environment Microbiological Criteria for Total Body Contact Recreational Use. The July survey extended from July 6th to August 13th and a clear pattern in the water quality of the lake was observed. The bacterial densities were low in the main portion of the lake, while the locations at the mouth of inflowing streams were found to be high in fecal streptococcus and total coliform levels which often exceeded the Recreational Criteria. Corresponding fecal coliform densities were low which indicated that the input of bacteria was of natural or animal origin. The total coliform density of the bottom waters was lower than that of the surface. Total coliform and fecal streptococcus bacterial levels rose throughout the summer and dropped in the fall. Fecal coliform levels in contrast, rose only after rainfall in the late summer. Special inshore stations were established to observe the rainfall effect more closely. The density of fecal coliforms at these locations varied very little in the dry weather but after a heavy rain (2.37 inches) pronounced increases were observed, some of which exceeded The Recreational Criteria. It is possible that some of these bacteria were washed from cottage waste disposal systems after the rain as well as from surface runoff. Further experiments will be carried out to define this phenomenon. The findings on Harp Lake, however, indicated that the magnitude of the change in bacterial densities following a rainfall greatly exceeded the dry weather daily variations.

Chemically, Harp Lake is typical of soft-water Precambrian Shield lakes having low concentrations of dissolved mineral constituents. A low, to moderate degree of enrichment was indicated by Secchi disc visibilities, chlorophyll a and nutrient concentrations in the illuminated surface waters of the lake. By late summer and fall, depletion of bottom water dissolved oxygen had occurred to the extent of being detrimental to cold water fish species such as lake and speckled trout.

PURPOSE OF THE SURVEYS

As a result of human activity in the recreational lake environment, some wastes may reach the lake itself and this can lead to either or both of two major types of water quality impairment: microbial contamination, and excessive growths of algae and aquatic plants. While the two problems can result from a common source of pollution, the consequences of each are quite different.

Microbial contamination by raw or inadequately treated sewage does not significantly change the appearance of the water but poses an immediate public health hazard when the water is used for drinking or swimming. This type of pollution can be remedied by preventing wastes from reaching a lake. If this is the only source of pollution, satisfactory water quality will then return since disease causing bacteria do not usually persist in lake water.

Problems due to nutrient enrichment may be long lasting even if further excess nutrients are prevented from entering the lake. Nutrient enrichment, or eutrophication, results from the addition of plant fertilizers which occur naturally and which are also present in virtually all forms of raw or treated human wastes. High concentrations of these fertilizers (plant nutrients), mainly nitrogen and phosphorus, can support excessive growths of rooted aquatic plants and of microscopic free-floating plants called algae.

While aquatic weed beds provide shelter, and both algae and rooted plants provide food for many kinds of fish, excessive growths of either are undesirable since they can upset the oxygen balance in the lake, interfere with recreational uses, and greatly affect the lake's appearance. They do not, however, generally pose a health hazard.

In order to detect either of these conditions, the surveys were designed, and tests selected, to evaluate the current condition of the lake with respect to:

- lakeshore development
- the distribution and abundance of bacteria
- changes in temperature, dissolved oxygen and water quality with depth
- plant nutrients and suspended algae
- densities and species of aquatic plants

DESIGN OF THE SURVEYS

Sampling Locations and Frequency

A proper estimate of the bacterial population requires several measurements of bacterial densities over a period of time which can then be averaged as a geometric mean. Measurements over 5 consecutive days at each station are regarded as the minimum number which when taken at many lake stations will give reliable bacteriological results.

Bacteriological, chemical and biological investigations were carried out during spring, summer and fall surveys from May 22 to June 2, from July 5 to August 13 and from September 10 to 15. Results from nine additional chemical and biological samplings carried out on Harp Lake between June and December 1973 by staff of the Ministry not directly associated with the Recreational Lakes Programme have been incorporated into the present report.

Samples for bacterial analysis were taken daily one meter below the surface at 25 stations established throughout the lake, as well as from one meter above the bottom at each mid-lake station (Figure 1).

During the surveys, chemistry sampling was based on consecutive six day periods and samples were collected on the first and fifth days of each period at the mid-lake, inlet and outlet stations. Samples for chlorophyll analyses were collected daily at mid-lake stations and on the first and fifth days at inlet stations. In addition to these surface samples (as composite samples through the illuminated surface waters), water was collected from 1 m above bottom at the mid-lake locations for chemical analyses.

Aquatic plant samples were obtained from areas representative of sparse, medium and dense growth.

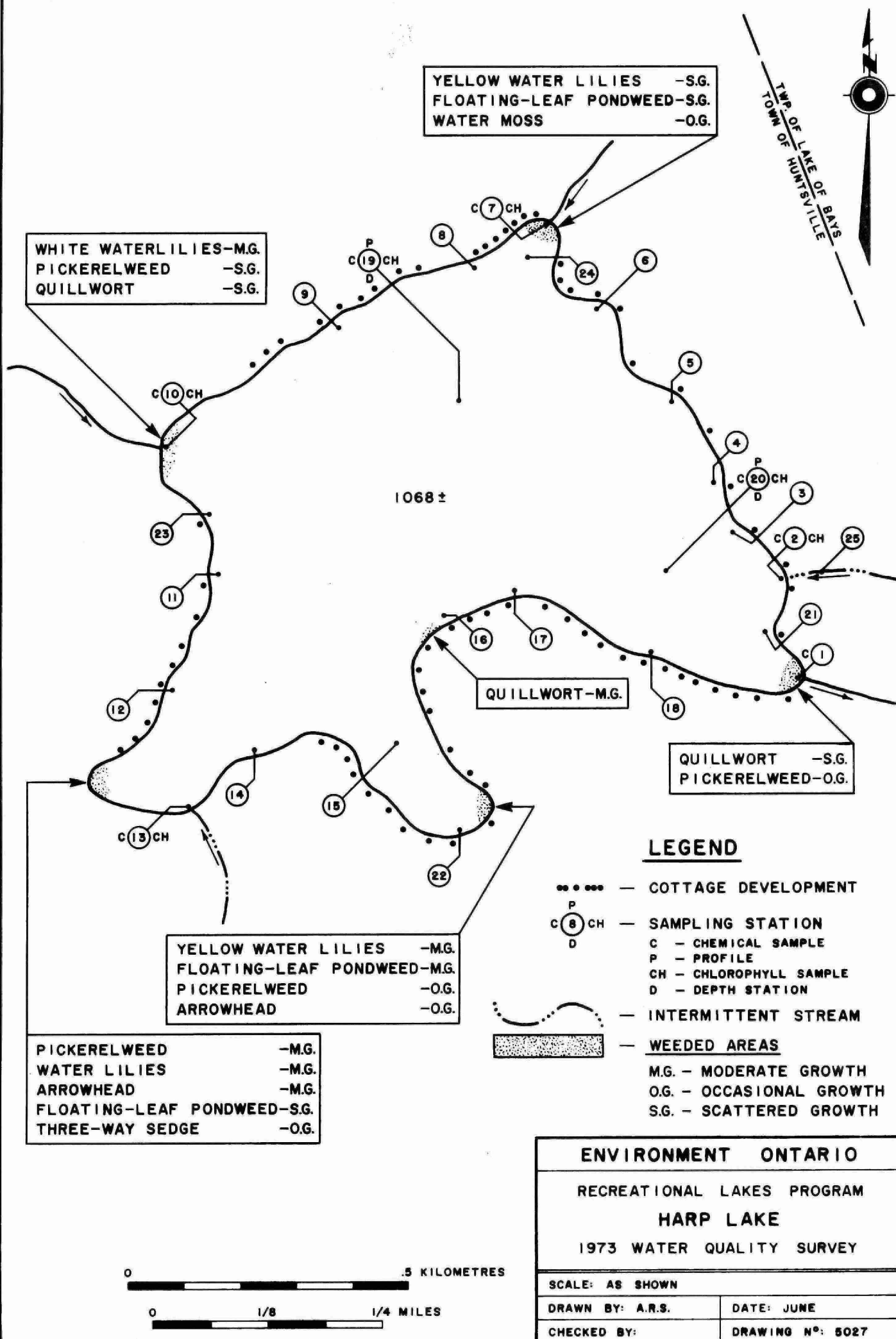
Field Tests

The variations in temperature and dissolved oxygen values with depth were measured at the two deep water stations with an electronic probe lowered into the lake and water clarity was measured with a Secchi disc (Figure 1). The pH of the samples was also measured in the field.

Bacteriological Tests

The numbers of bacteria in each of three types of "indicator" organisms were determined on each sample. The three bacterial types, total coliform, fecal coliform and enterococcus (fecal streptococcus)

FIGURE 1 - STATION LOCATIONS, LAKESHORE DEVELOPMENT AND MAJOR AREAS OF SHORELINE AQUATIC PLANT GROWTH OF HARP LAKE



The "Secchi Disc Reading" is obtained by averaging the depth at which a 23cm (9") dia. black and white plate, lowered into the lake just disappears from view and the depth where it reappears as it is pulled up.

Most of the free-floating algae are suspended in the illuminated region between the lake surface and 2 times the Secchi disc reading.

Secchi Disc Reading

Clear, algae-free lake:
Secchi disc readings tend to be greater than 3m (9 feet).

Turbid or algae-rich lake:
Secchi disc readings tend to be less than 3m (9 feet).

2 times Secchi disc reading

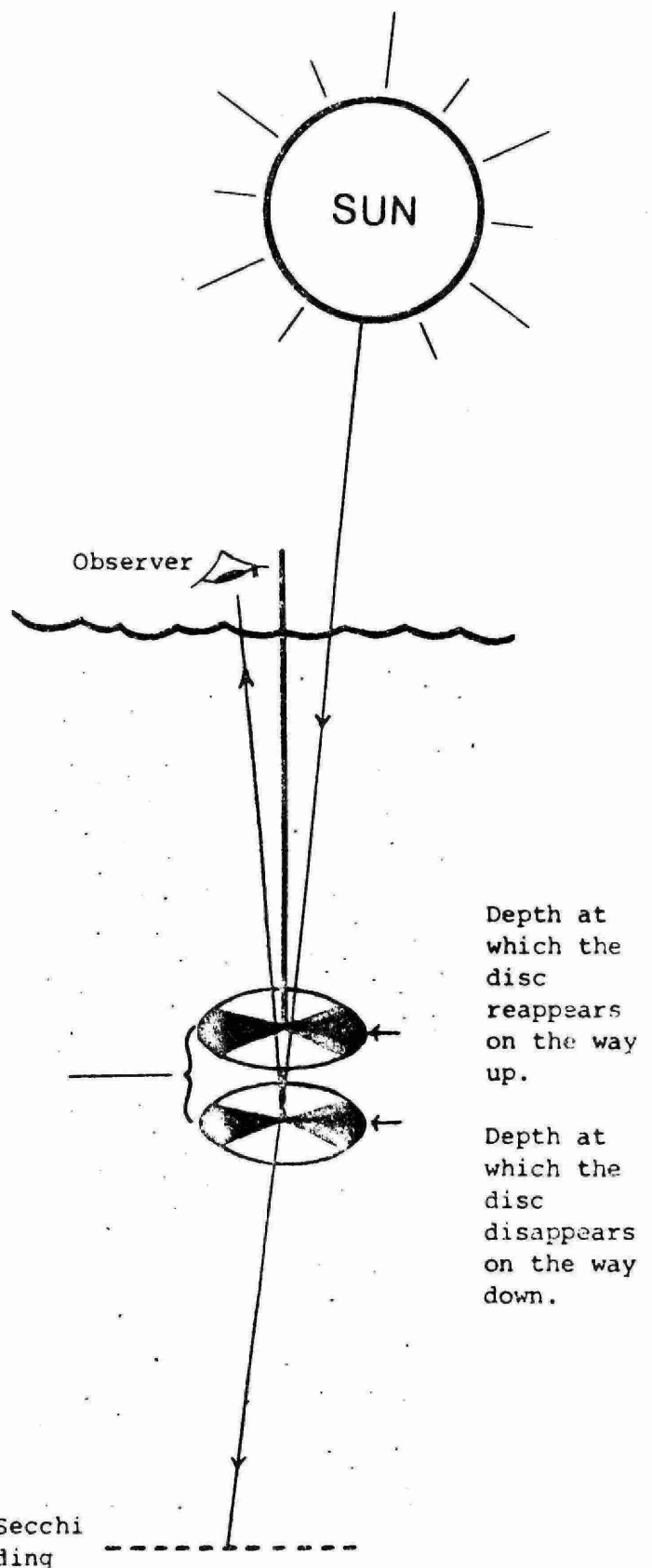


FIGURE 2: USE OF SECCHI DISC TO DETERMINE WATER CLARITY

bacteria are all indigenous to man and other warm blooded animals, and are found in the colon and feces in tremendous numbers. Many diseases common to man can be transmitted by feces, consequently, the probability of occurrence of these diseases is usually highest in areas where the water is contaminated. These indicator organisms in water connote the possible presence of disease causing organisms.

The density (numbers per 100 ml) of the indicator bacteria in water will vary considerably between pairs of samples taken at the same station, or at different stations on a lake, or if taken at different times, and so the assessment of water quality cannot be determined accurately from a single water sample.¹ Therefore the bacteriological surveys require many samples to be taken at several lake stations over a period of time, and following this the large amount of data so obtained is reduced by calculation to meaningful and easily manipulated statistics.

These data were then evaluated by statistical techniques in the following manner. The geometric mean,¹ (the most appropriate central value) and standard deviation were calculated for the values of each bacterial type at every station, providing concise valid data. Statistically significant variations in the bacterial densities between stations, or groups of stations, were determined by selected statistical techniques². By these means the data from each station were tested against that of every other station until all stations with similar geometric mean densities were separated into groups (Group A, B---).

The group results, and those for individual stations, were then displayed on a map of the lake with each group identified by different stippling. Within each stippled area the group geometric mean applied for each type of bacteria, unless otherwise indicated by individual station values. The areas of better or worse bacterial quality were defined by the group geometric mean densities, and so any inputs of bacterial contamination, and the areas they affect, were readily identified.

Chemical Tests

Hardness, alkalinity, chloride, iron and conductivity were measured in order to define the mineral composition of the water. The types of plants and animals which thrive, effects of toxic materials

¹Guidelines and Criteris for Water Quality Management in Ontario MOE 1973

²An Analysis of Variance and Bartlett's Test of Homogeneity.

and suitability of the lake for various management techniques are affected by the mineral content.

Total and soluble phosphorus were measured in the inlet and bottom water samples while total phosphorus only was measured in the mid-lake and outlet surface samples. Soluble phosphorus concentrations are used mainly to substantiate various interpretations of the total phosphorus concentrations.

The total Kjeldahl nitrogen is (apart from ammonia, nitrogen) essentially the amount of nitrogen contained on organic material. It was measured in all of the chemical samples. The soluble forms of nitrogen (ammonia, nitrite and nitrate) were measured in the inlet and bottom water samples. They are particularly important in bottom waters since nitrogen may be regenerated from decaying organic matter in these forms.

Chlorophyll a concentrations are an indication of the amount of suspended algae in the water. The live algae are confined mainly to the illuminated surface waters which extend down to a depth of about twice the Secchi disc reading. The chlorophyll samples were collected by filling the sample bottle as it was lowered and raised through the depth of the illuminated surface waters. The sample was then representative of the algal density through the sampling depth.

DESCRIPTION OF THE HARP LAKE AREA

Lake and Soil Characteristics

Harp Lake is approximately 10 kilometers (6 miles) northeast of Huntsville, in Chaffey township, District of Muskoka. The lake has a water surface area of 0.7 square kilometers (180 acres) contained by approximately 4 kilometers (2.5 miles) of shoreline. The maximum depth of the lake is 36 meters (118 feet).

Harp Lake is located in the North Muskoka River Drainage Basin, which is part of the greater Muskoka River Drainage Basin. The lake's drainage basin comprises an area of 2.3 square kilometers (600 acres).

There are four inflows into Harp Lake, of which two are only intermittent streams. One outflow occurs at the east end of the lake and this eventually flows into Peninsula Lake.

The majority of the shoreline is characterized by coarse-textured soils with Precambrian Rock at 0.3 m depth or less. The dominant soil family is Montegale, which is a well-drained sandy loam. The slope of the shore ranges from gentle to steep.

Lakeshore Development and Water Usage

There are approximately 73 cottages on Harp Lake (Figure 1), many of which have been built in the last 10 years. The lake is generally heavily developed, and the immediate shoreline is well-treed with birch. There are several areas of light development, including the area between the outlet (Station 1) and inlet Station 2, where a steep cliff has impeded cottage development. Another sparsely developed area is that surrounding inlet Station 10, while the largest uncottaged area is along the south shore of the southwest bay, approximately between Stations 13 and 14. There are no commercial establishments on the lake.

Most cottagers use the lake as their source of domestic water supply. It should be noted that no surface water is considered safe for human consumption without prior treatment, including disinfection by boiling or chlorination (see P.A-2 for explanation). Recreational uses of the lake include swimming, angling, and boating, with sailboats and canoes being very popular. Game fish species present include speckled trout, lake trout and smallmouth bass. Winter recreational uses of the lake (ice skating and snowmobiling) are prevalent on occasion.

RESULTS AND DISCUSSIONS

Bacteriology

In May, July and September the bacteriological water quality of Harp Lake in 1973 was generally very good, and with the exception of the mouth of the four inflows, was within the Ministry of the Environment Microbiological Criteria for Total Body Contact Recreational Use which states:

¹*'Where ingestion is probable, recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC) and/or enterococcus (fecal streptococcus FS) geometric mean density exceeds 1000, 100 and/or 20 per ml respectively, in a series of at least ten samples per month.....'*

In May, the geometric mean densities for the major portion of the lake were 13 TC, 1 FC and 2 FS per 100 ml (Group A; Figure 3). The four main inflows and the outflow displayed higher bacterial levels than the main body of water. Total coliform and enterococcus densities were highest at the northern inflow (Stn. 7) with values of 227 TC, and 25 FS per 100 ml. Another stream to the southwest (Stn. 10) had higher bacterial densities of 205 TC and 15 FS per 100 ml. The inflowing stream in a southwest bay (Stn. 13) and the stream on the east shore (Stn. 2) were intermittent with bacterial densities of 223 TC and 11 FS per 100 ml, and 119 TC and 12 FS per 100 ml respectively. Inflows often have higher bacterial levels than the rest of the lake as they can carry materials such as soil, decaying matter and possibly animal and human wastes into the lake. A total coliform mean of 50 TC per 100 ml was recorded at the outflow (Stn. 1) which was slightly higher than the mean for the main body of water. Low total coliform levels of 2 TC per 100 ml were found for the bottom waters (Stns. 19D and 20D).

¹Guidelines and Criteria for Water Quality Management in Ontario, 1973.

The second survey on Harp Lake extended from July 6th to August 13th. In order to show a clearer picture of the water quality, the data were divided into seven day segments (Figures 4 - 9). A clear pattern was seen in the data. The bacterial densities for the major portion of the lake were low. Very high fecal streptococcus densities, which usually exceeded the Recreational Criteria, and high total coliform densities, which occasionally exceeded the Recreational Criteria, were found at the mouth of all inflowing streams. The corresponding fecal coliform densities were low which indicated that the input of bacteria was of natural or animal origin. The bottom waters (Stns. 19D and 20D) consistently had lower total coliform densities than the surface waters (Figures 4,5,7,8,9). The bacterial levels climbed throughout the summer (Figure 11) until in the August 10th - 13th survey the density of fecal streptococcus for the main body of the lake exceeded the Recreational Criteria with a value of 21 FS per 100 ml (Group A; Figure 9).

The mean bacterial densities for the main body of Harp Lake in September were 25 TC, 1 FC and 1 FS per 100 ml (Group A; Figure 10). Elevated bacterial levels were found at two of the inflows; the northern stream (Stn. 7) with means of 190 TC and 9 FS per 100 ml. and the inflowing stream on the west shore (Stn. 10) with densities of 529 TC and 104 FS per 100 ml. The outflow (Stn. 1) also exhibited high total coliform and enterococcus values of 292 TC and 7 FS per 100 ml.

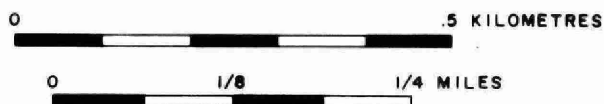
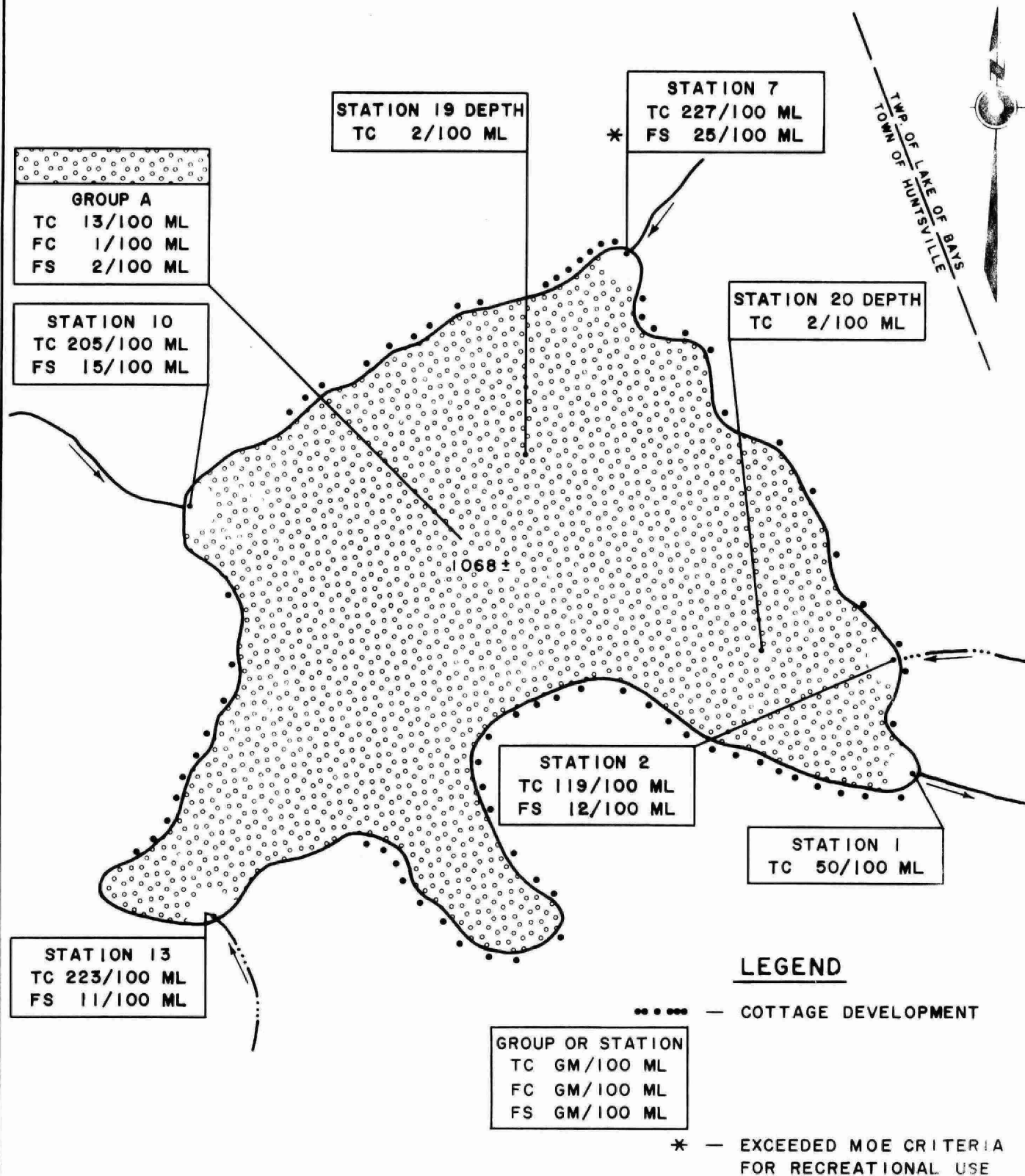
To compare the surveys more clearly the mean bacterial densities for the main body of the lake were plotted at the survey mid-point with weekly rainfall totals plotted at the week mid-point (Figure 11). Rainfall data were obtained at the Huntsville Sewage Treatment Plant. Total coliform and fecal streptococcus levels rose through the summer, peaked in early August, and dropped in the fall. A very rapid drop in fecal streptococcus levels occurred towards the end of August so that during the September survey they were close to zero. The fecal coliform densities, for the main body of the lake, did not appear to follow this pattern but rose only after rainfall in the late summer.

It has often been observed that following a rainfall, bacterial levels increase and may remain elevated for a number of days. To demonstrate this 'rainfall effect' more clearly, extra sampling points, much nearer to the shore (8') than the routine stations, were placed in four cottaged areas (Figure 12), directly in front of cottages in most cases. Daily geometric means for fecal coliforms were calculated for each group, and plotted with the quantity of rain for each day, measured at the Huntsville Sewage Treatment Plant. During the dry period, July 10th to July 24th, fecal coliform levels generally fluctuated between 1 FC and 6 FC per 100 ml. However, after 60.3 mm (2.37 inches) of rain, pronounced increases in the fecal coliform densities were observed at all locations, and, at some sampling sites, exceeded the Recreational Criteria (Figure 13).

It was difficult to conceive of a natural source of fecal coliforms which could have contributed the high levels of these bacteria to the lake after rainfall. The results suggested that after the rain the bacteria were washed from the cottaged areas, either in surface runoff or as seepage from waste disposal systems. Further experiments and controls were considered necessary to firmly define these findings. The findings on Harp Lake have, however, provided more reliable data and supported the previously observed 'rainfall effects' on other cottaged lakes. The longer observation periods showed that the magnitude of the change in bacterial densities following a rainfall greatly exceeded the dry weather daily variations. The bacterial densities returned to pre-rainfall levels in 2 to 3 days.

The survey on Harp Lake in 1973 was also part of a study to provide a data baseline for lakes in southern Ontario. The companion undeveloped lake was Jerry Lake, located about one mile to the east. The rainfall effect on fecal coliform levels detected in the main body of Harp Lake (Figure 11) was not present in Jerry Lake surveyed at the same time.

**FIGURE 3 - DISTRIBUTION OF BACTERIA FOR
THE MAY 23 TO JUNE 2 SURVEY**



ENVIRONMENT ONTARIO

RECREATIONAL LAKES PROGRAM

HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

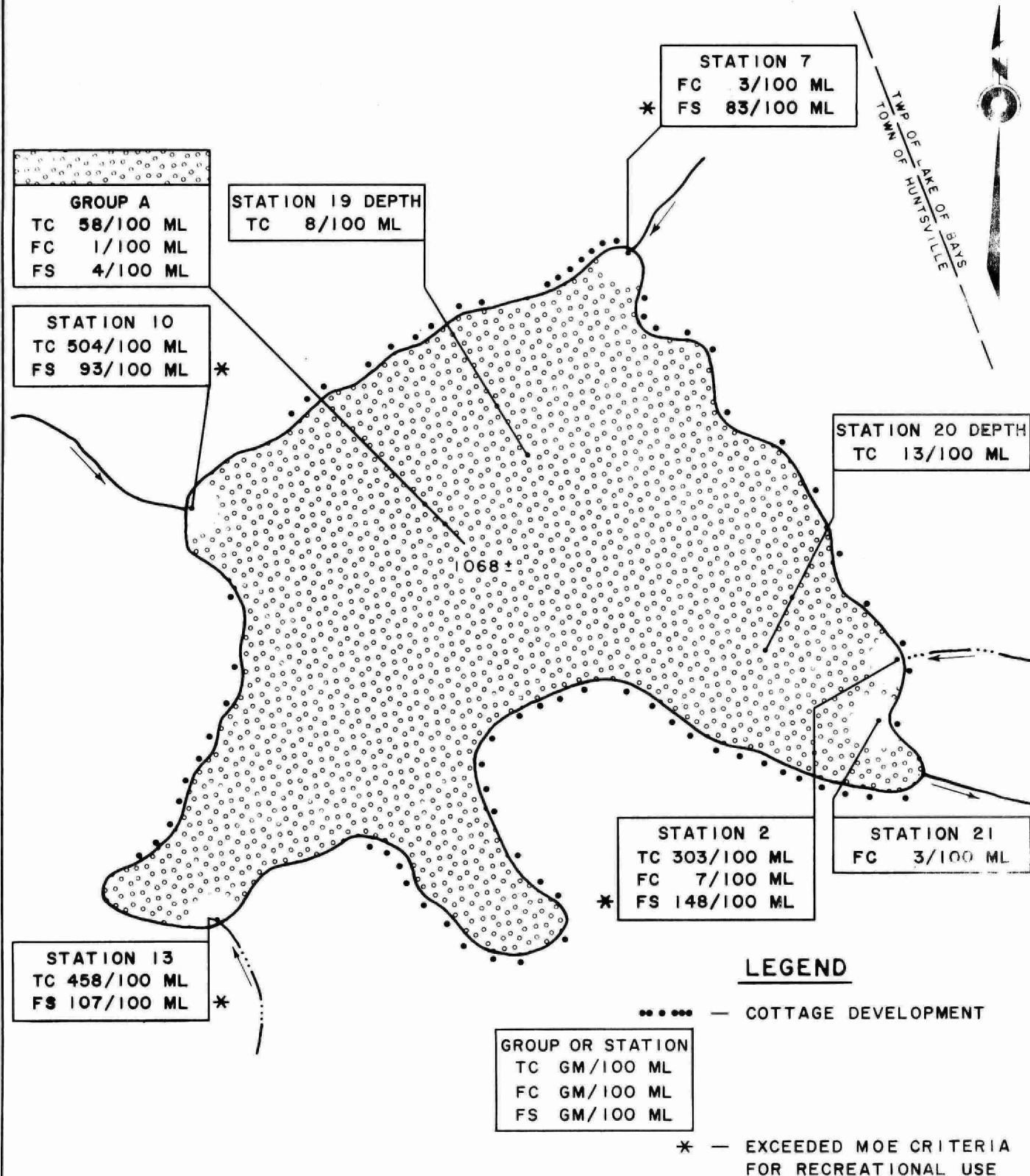
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DATE: JUNE

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FIGURE 4 - DISTRIBUTION OF BACTERIA FOR
THE JULY 6 TO JULY 12 SURVEY



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RECREATIONAL LAKES PROGRAM

HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

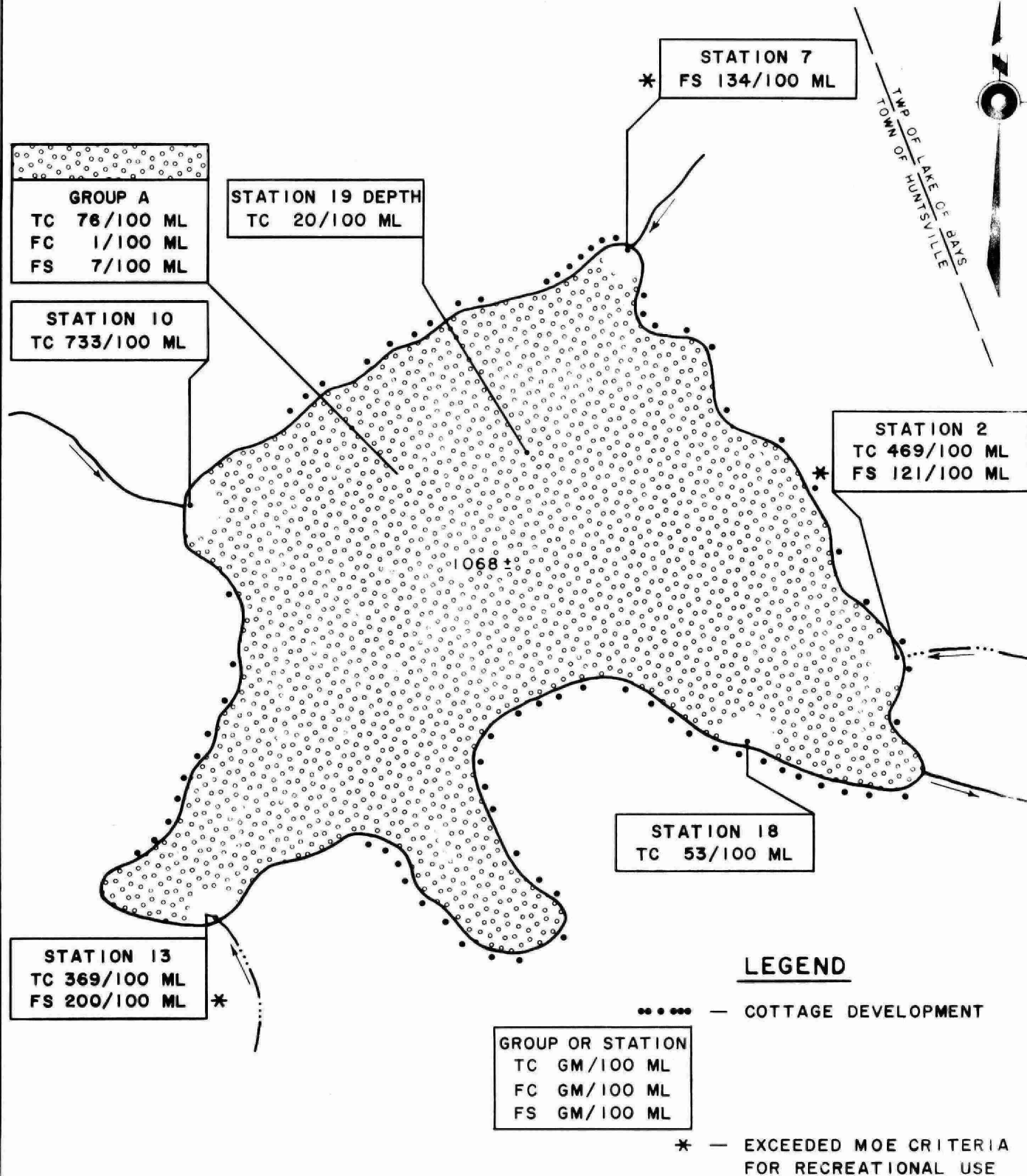
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**FIGURE 5 - DISTRIBUTION OF BACTERIA FOR
THE JULY 13 TO JULY 19 SURVEY**



0 5 KILOMETRES

0 1/8 1/4 MILES

ENVIRONMENT ONTARIO

RECREATIONAL LAKES PROGRAM

HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

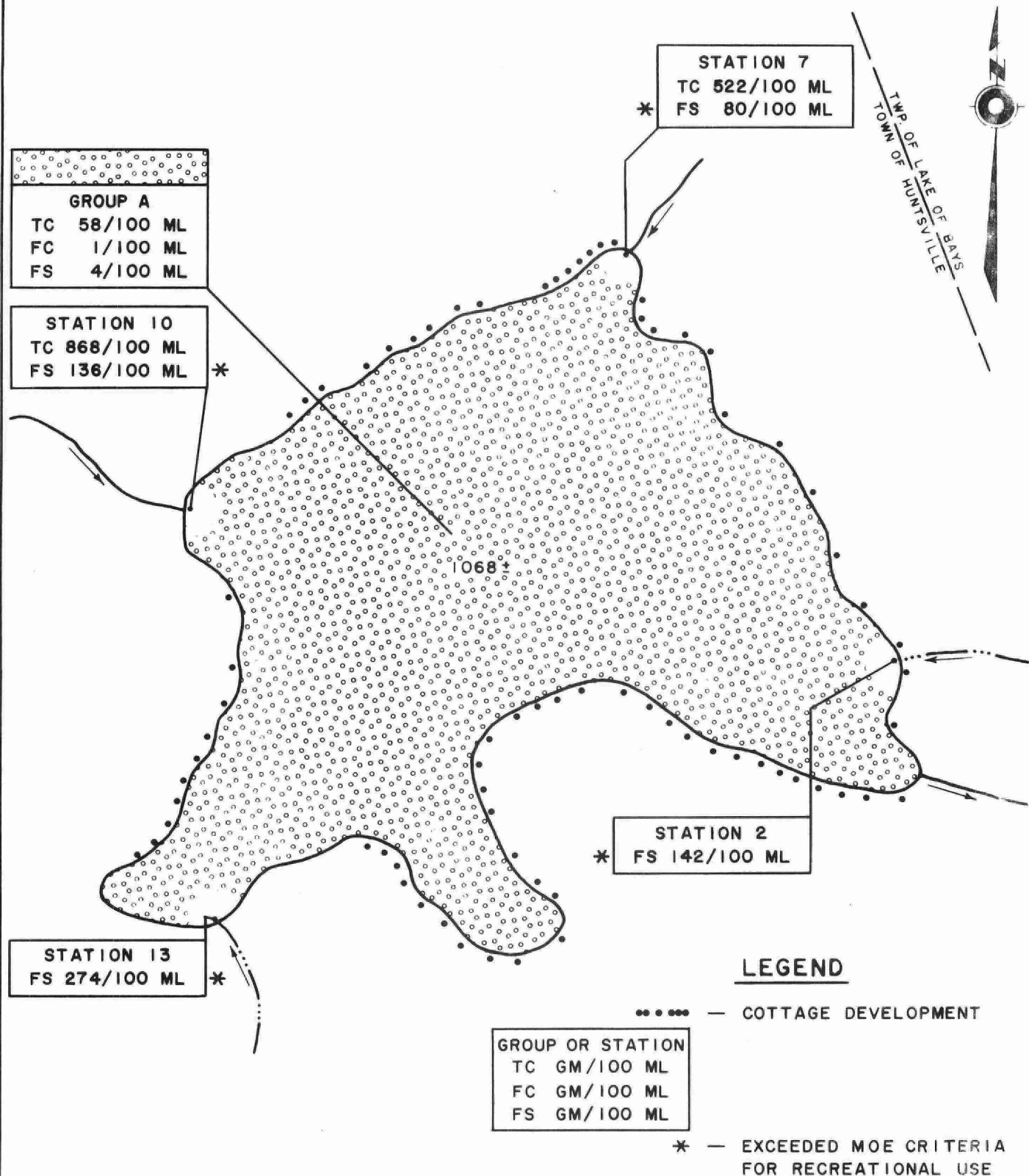
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DATE: JUNE

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**FIGURE 6 - DISTRIBUTION OF BACTERIA FOR
THE JULY 20 TO JULY 26 SURVEY**



0 .5 KILOMETRES

0 1/8 1/4 MILES

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RECREATIONAL LAKES PROGRAM

HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

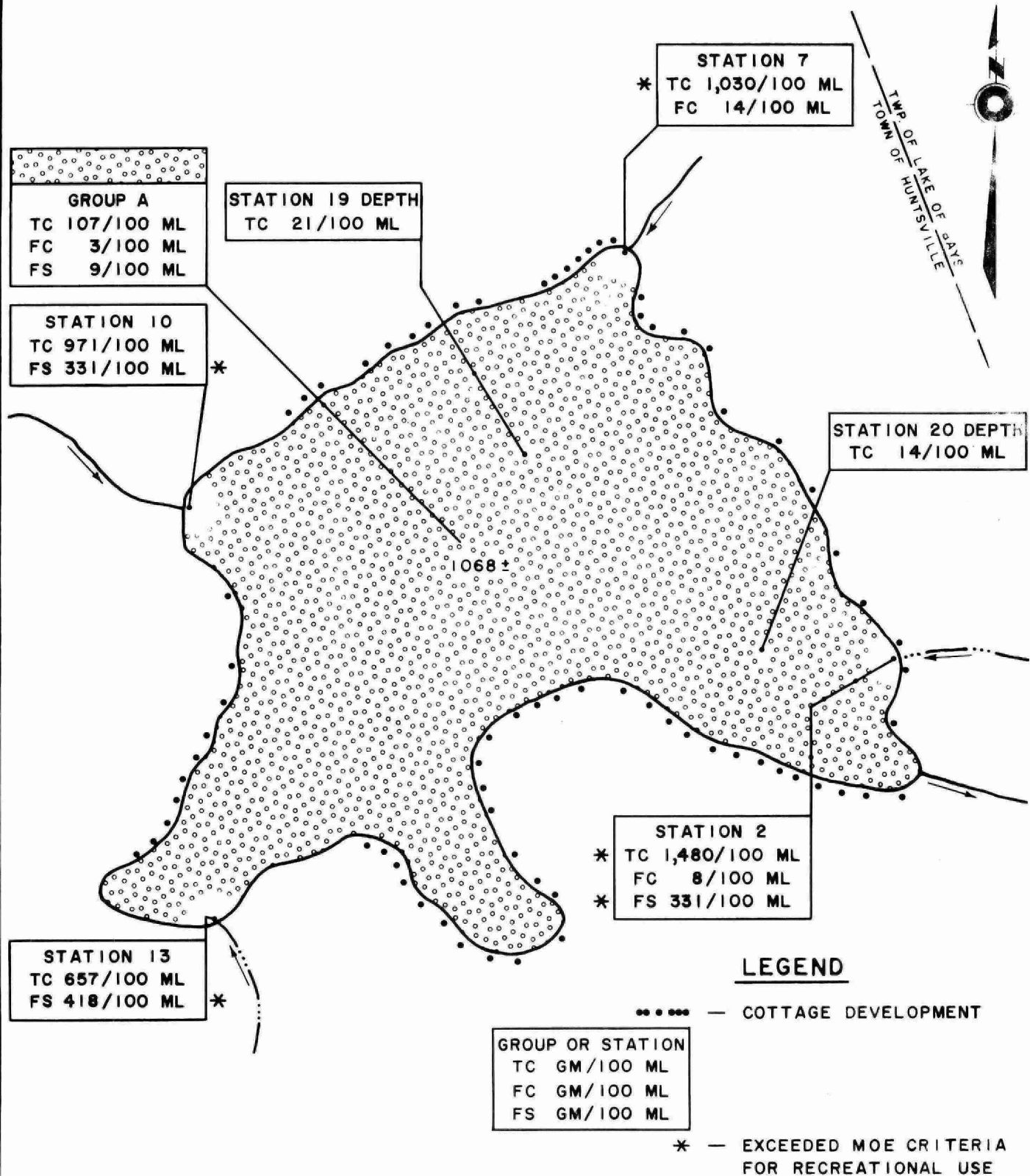
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**FIGURE 7 - DISTRIBUTION OF BACTERIA FOR
THE JULY 27 TO AUG. 2 SURVEY**



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HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

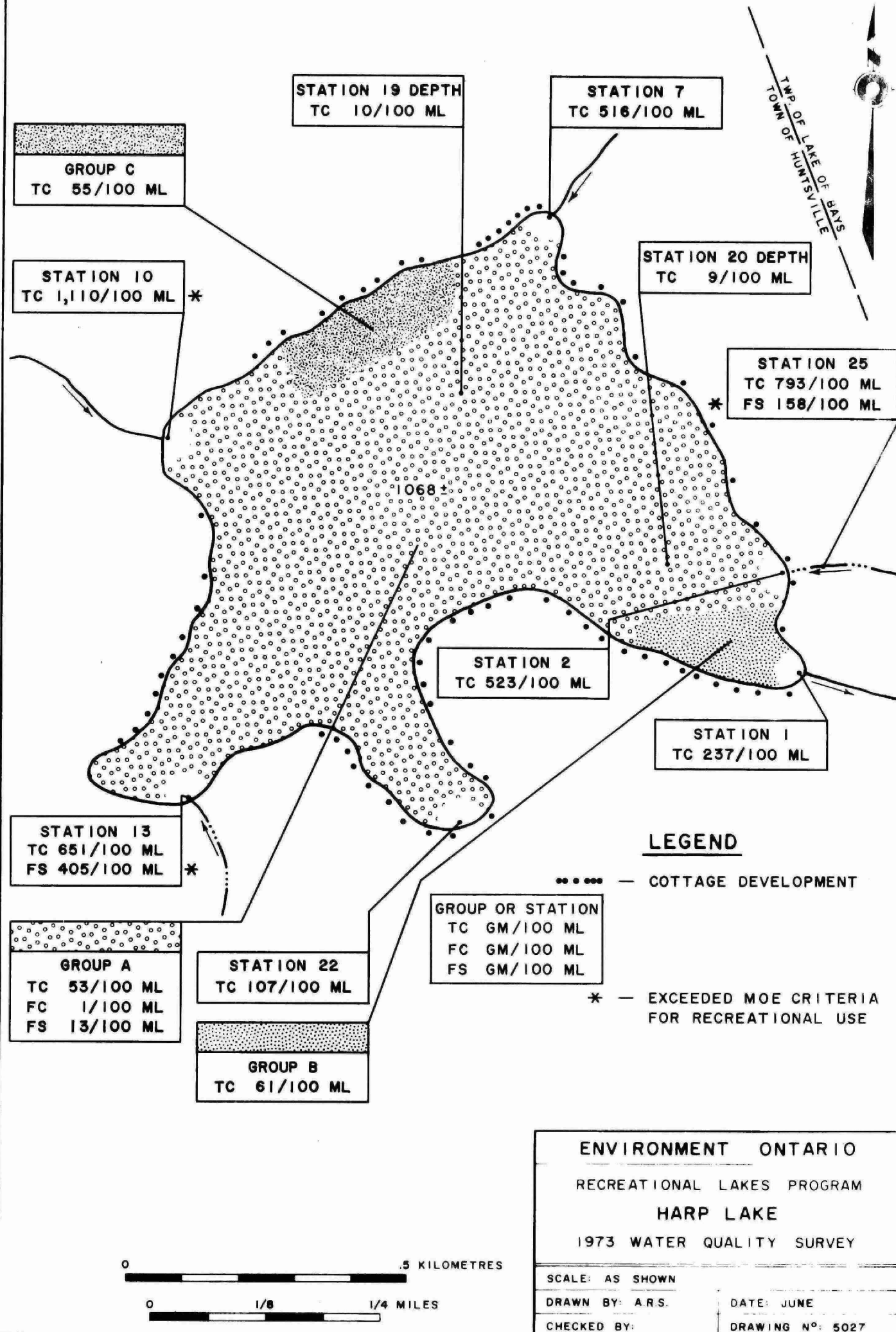
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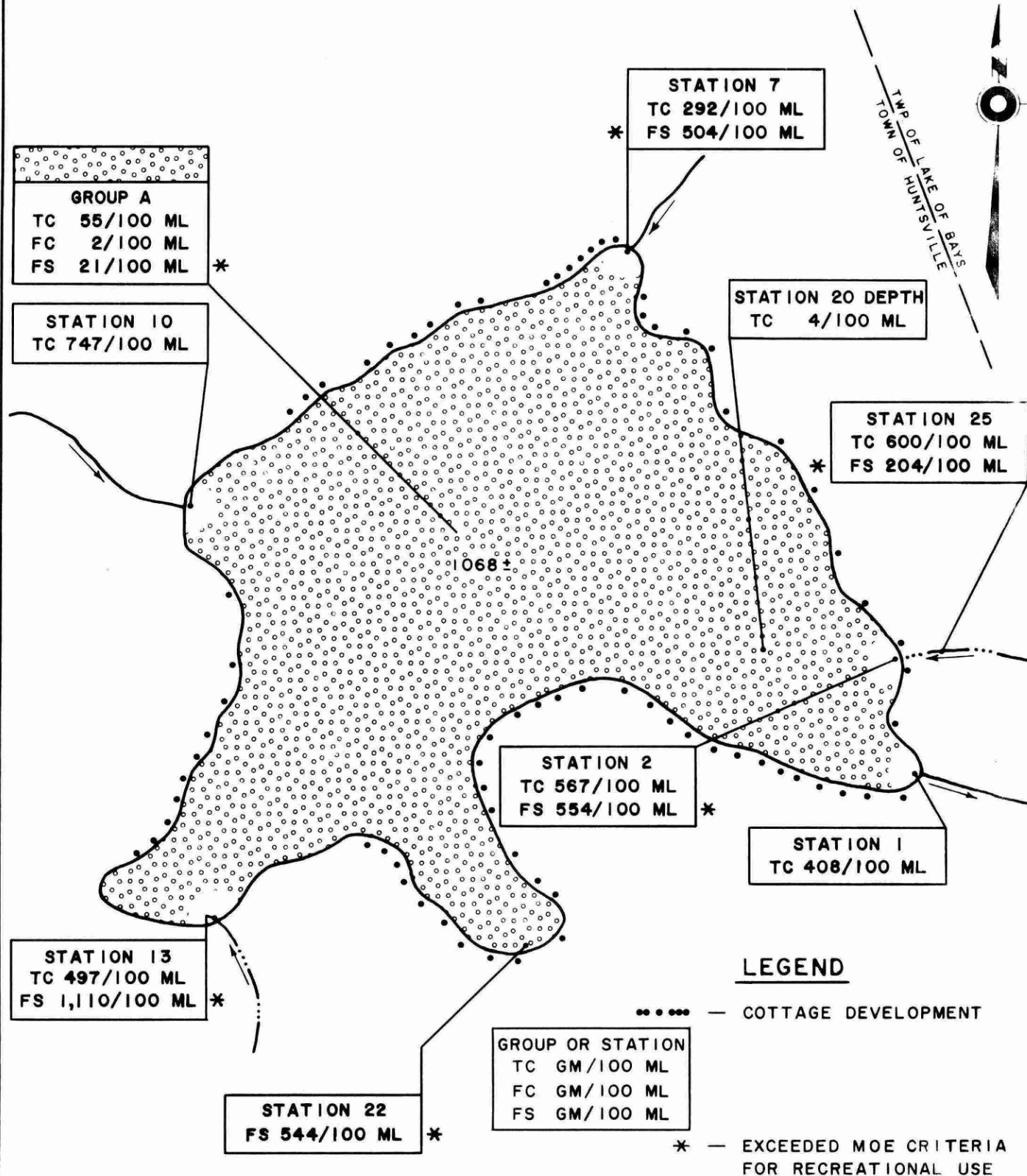
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FIGURE 8 - DISTRIBUTION OF BACTERIA FOR
THE AUG. 3 TO AUG. 9 SURVEY



**FIGURE 9 - DISTRIBUTION OF BACTERIA FOR
THE AUG. 10 TO AUG. 13 SURVEY**



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1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

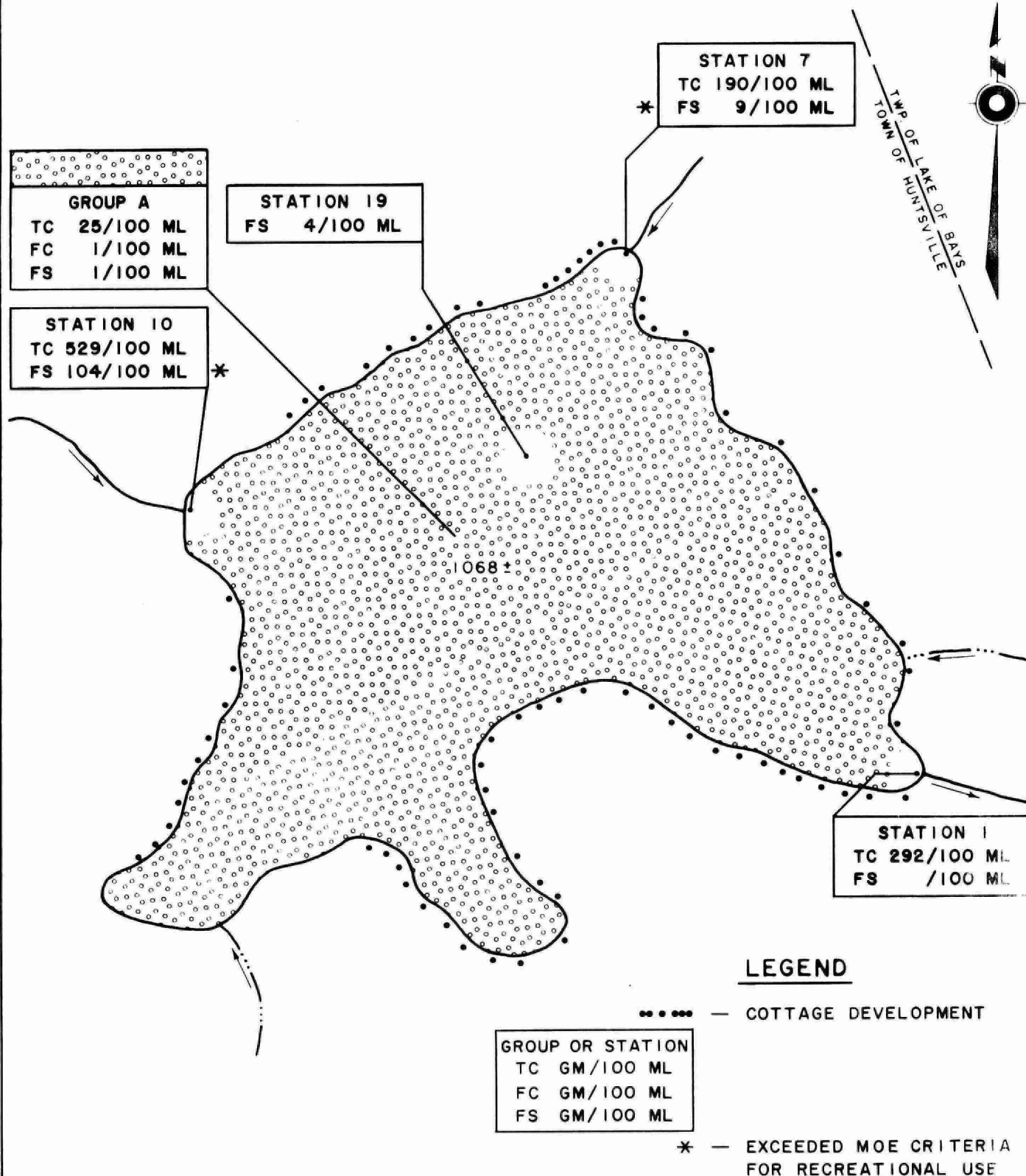
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FIGURE 10 - DISTRIBUTION OF BACTERIA FOR
THE SEPT. 10 TO SEPT. 15 SURVEY



0 .5 KILOMETRES

0 1/8 1/4 MILES

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HARP LAKE
1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

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FIGURE 11 - BACTERIAL DENSITIES AND RAINFALL FOR HARP LAKE

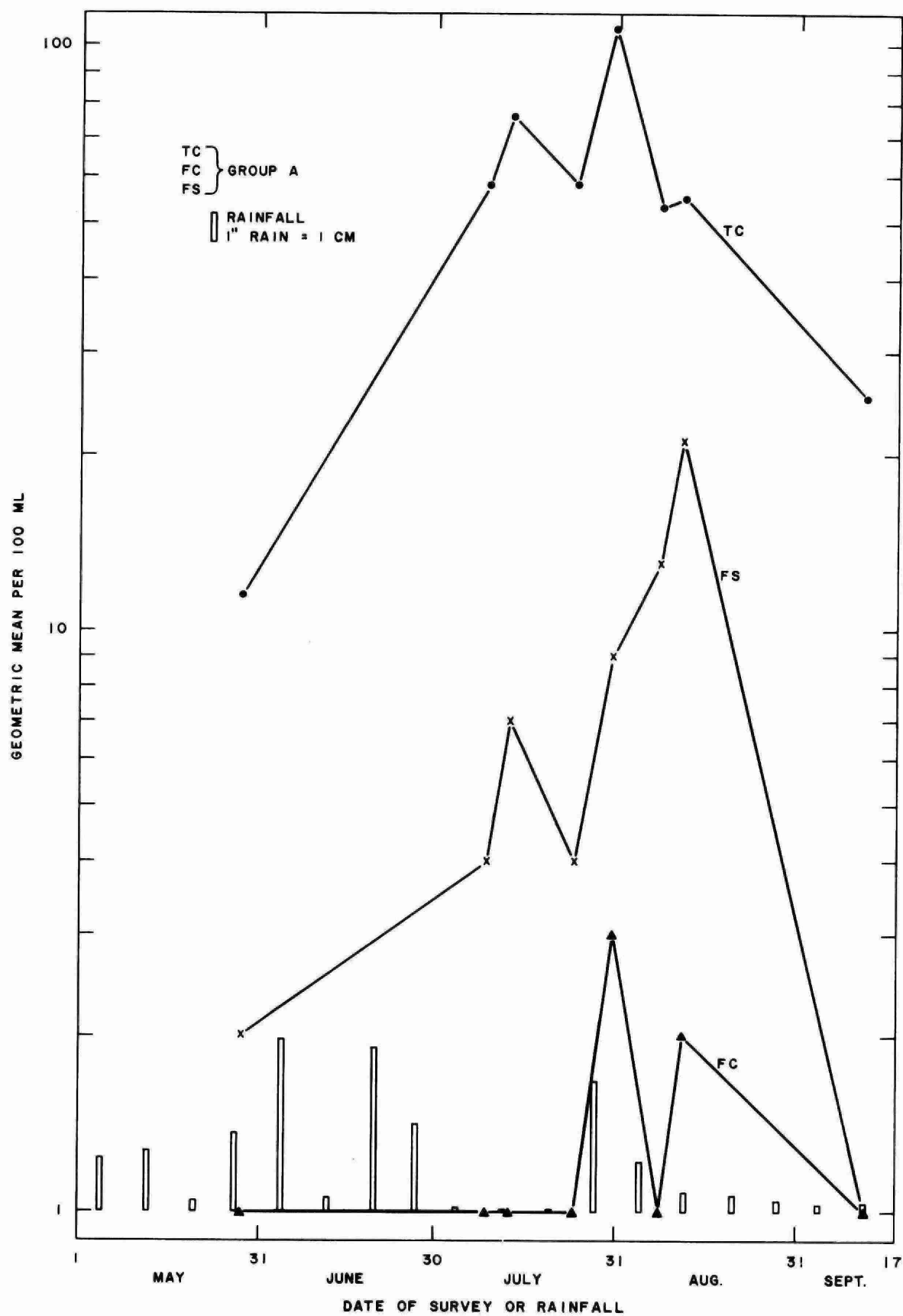
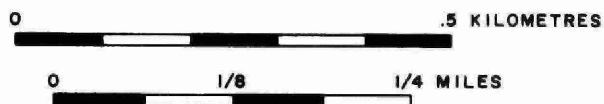
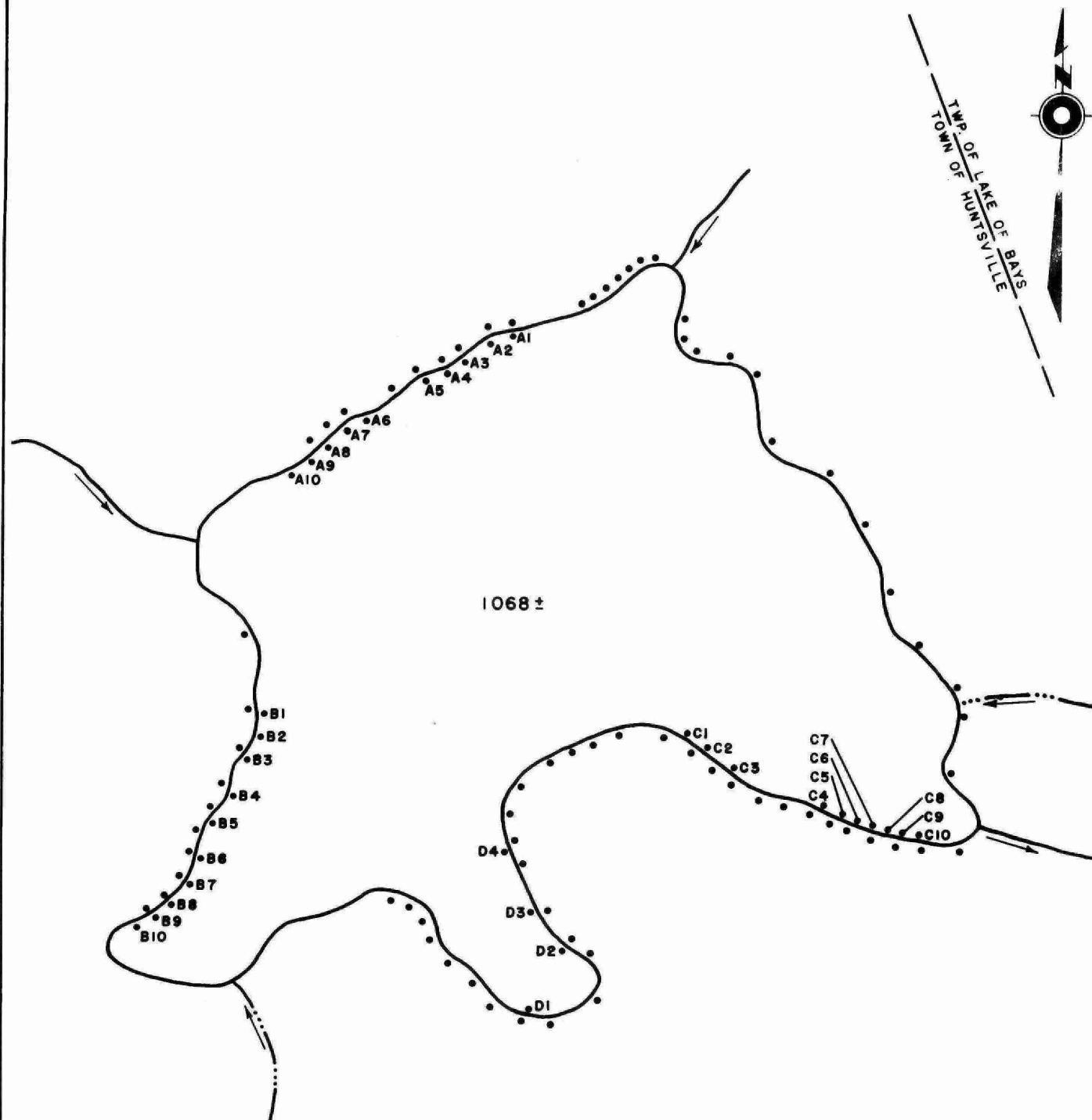


FIGURE 12 - LOCATION OF INSHORE SERIES OF SAMPLING LOCATIONS



ENVIRONMENT ONTARIO

RECREATIONAL LAKES PROGRAM

HARP LAKE

1973 WATER QUALITY SURVEY

SCALE: AS SHOWN

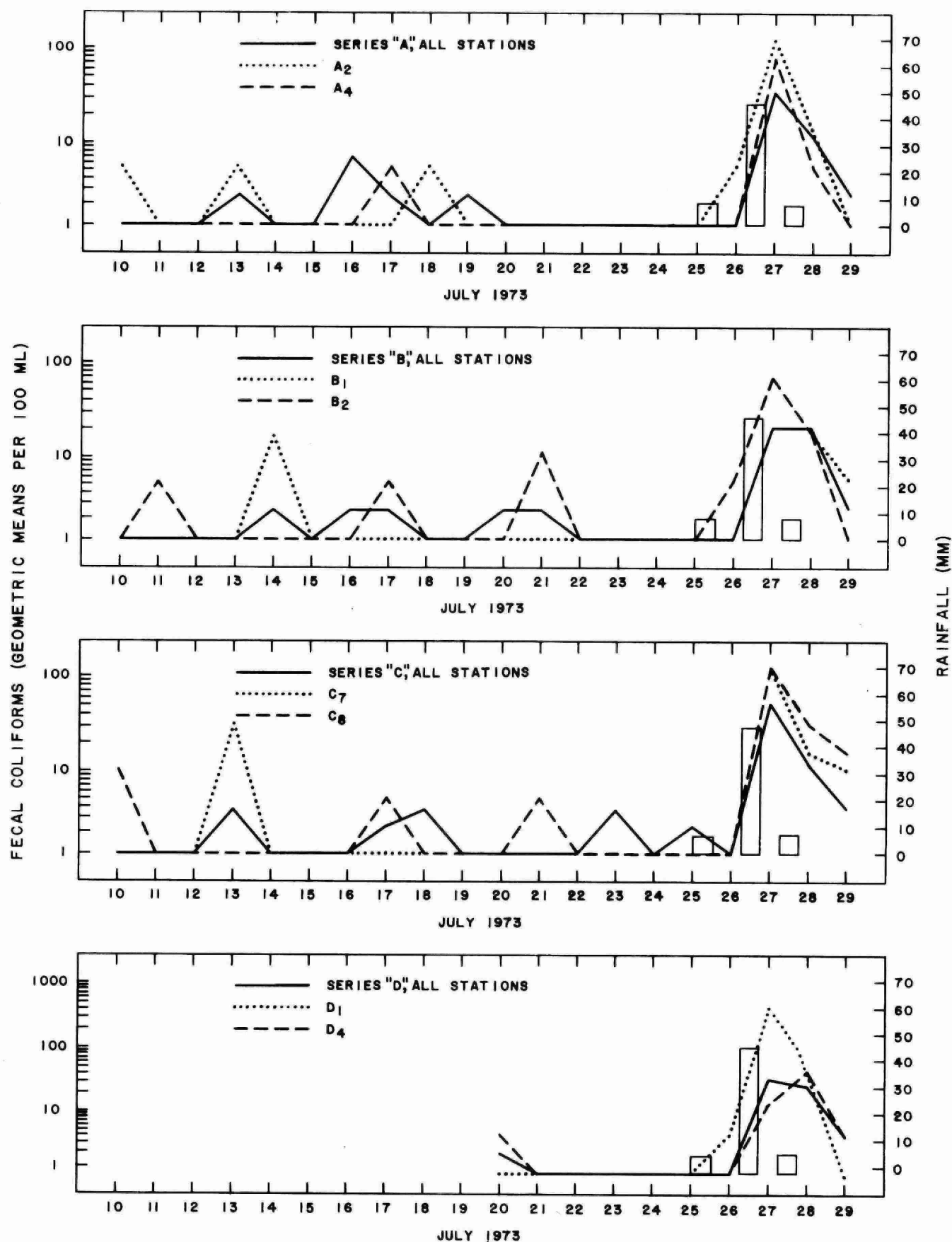
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FIGURE 13 - FECAL COLIFORM DENSITIES IN INSHORE AREAS OF HARP LAKE BEFORE AND AFTER RAINFALL



Chemistry

Routine Lake Stations

A zone of rapid temperature decline (thermocline) was observed in Harp Lake during all three surveys and was of similar characteristics at both deep-water stations. During the first half of the spring survey, the thermocline occurred between the 2 and 5 meter depths, but this expanded to between 3 and 8 meters in the last half of the survey. In July, the thermocline was located between 3 and 9 meters, and by early August it increased to between 3 and 10 meters. During the fall survey, with the cooler surface temperatures, the thermocline was lower and was located between the 5 and 10 meter depths (Figure 14).

Dissolved oxygen concentrations in the surface waters at both mid-lake stations were at or near saturation for all three surveys. During the fall survey, Station 19 averaged only 12% saturation at 1 m above bottom, while the summer saturations averaged 20% (Figure 14). These values were lower than at Station 20, where both the summer and fall mean saturations 1 m above bottom were 30%. Cold water fish species such as lake trout will not thrive at this depth with these low dissolved oxygen levels. Late fall sampling indicated that the lake "turned over" between mid-November and the beginning of December (see page A- 6 for explanation), restoring dissolved oxygen to new saturated levels throughout the lake.

Harp Lake is a typical soft-water Canadian Shield lake, having low hardness, alkalinity, conductivity and pH values as indicated in the following table:

Overall Ranges

	<u>Hardness</u> <u>(mg/l as CaCO₃)</u>	<u>Alkalinity</u> <u>(mg/l as CaCO₃)</u>	<u>Conductivity</u> <u>(umhos/cm³)</u>	<u>Chloride</u> <u>(mg/l as Cl)</u>	<u>pH</u> <u>(units)</u>
Station 19	12-19	4-12	34-44	1-4	5.1-7.0
Station 20	11-19	5-8	34-43	1-2	5.2-6.9
Inlets	11-30	4-33	28-84	1-3	4.5-6.7
Outlet	11-21	5-9	34-38	1-2	5.4-6.6

STATION 19

STATION 20

TEMPERATURE (°C)

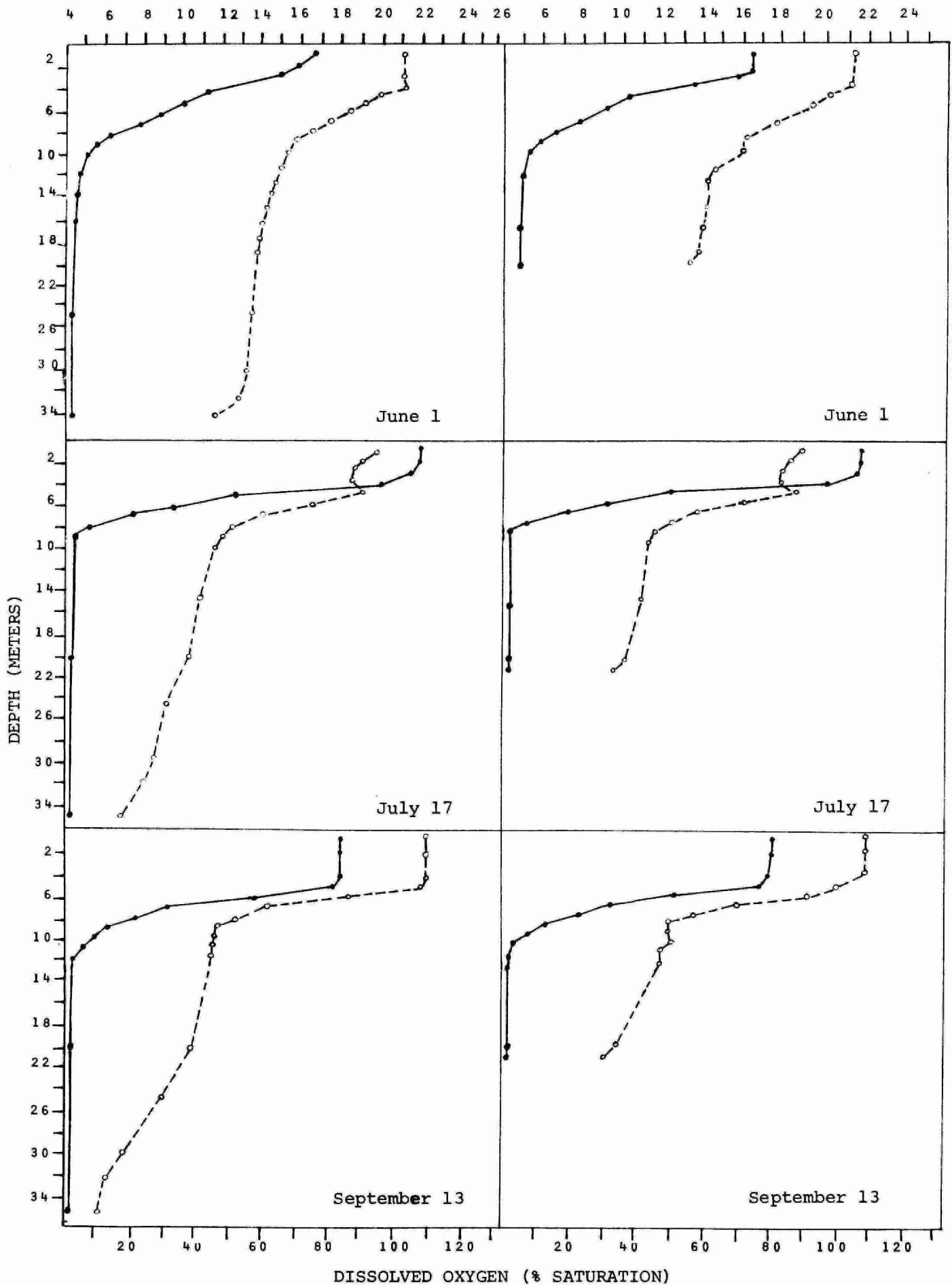


Figure 14: Dissolved oxygen (---) and temperature (—) profiles at Stations 19 and 20 on Harp Lake

The pH values at both deep-water stations were consistently lower in the bottom waters than at the surface as is common when dissolved oxygen has been depleted. The surface and bottom water pH means were 6.4 and 5.5 respectively for both stations. Especially low pH values of 4.5 at inlet Station 7 are attributed to bog drainage.

Phosphorus concentrations in the illuminated surface waters of the lake were consistently low, averaging 0.011 mg/l and 0.010 mg/l at Stations 19 and 20 respectively. Concentrations in the bottom waters were slightly higher, with means of 0.016 mg/l and 0.013 mg/l respectively. No seasonal trends in surface or bottom waters were evident. Phosphorus concentrations were high in the inlets, and were most significant at Station 13 where they averaged 0.065 mg/l for the spring survey and 0.20 mg/l for the summer survey. The mean concentration for the other three inlets was 0.041 mg/l.

The total Kjeldahl nitrogen concentrations were also consistently low in the surface waters, averaging 0.26 mg/l and 0.25 mg/l for Stations 19 and 20 respectively. The bottom water concentrations were very similar, averaging 0.25 mg/l and 0.24 mg/l respectively. At the inlets the concentrations were high, with an overall mean value of 0.63 mg/l during the study period. At Stations 2 and 13, there was an increase in total Kjeldahl nitrogen between the spring and summer but no other seasonal trends were evident.

Iron concentrations were minimal in the surface waters, averaging 0.05 mg/l for both stations, while higher mean values occurred in the bottom waters at Stations 19 (0.27 mg/l and 20 (0.14 mg/l). Concentrations at inlet Stations 2 and 13 were very high, with mean values of 2.6 mg/l and 1.5 mg/l respectively. An increase in the iron concentrations at these two inlets between the spring and summer surveys which correlated with the observed increase in phosphorus and total Kjeldahl nitrogen during the same period was noted. Inlet Stations 7 and 10 had a combined mean of 0.62 mg/l over the survey period. The high phosphorus, total Kjeldahl nitrogen, and iron values in the inlets are most likely to be natural in origin. Inlet Stations 2 and 13, which had the highest values, are only intermittent streams, and were not sampled during the fall survey when their flow was insignificant.

Samples for both sodium and potassium analyses collected through the euphotic zone indicated consistently low mean values of 1 mg/l. Similar samples for sulphate indicated a moderate mean of 10 mg/l during the three surveys.

The rather low concentrations of phosphorus, total Kjeldahl nitrogen, and iron in the bottom waters indicates that although the bottom water dissolved oxygen concentrations (especially at Station 19) were as low as 11% saturation (1.9 mg/l), regeneration of iron or other nutrients was not evident. The low dissolved oxygen concentrations were undoubtedly brought about by biochemical oxidation and bacterial decomposition of organic material (see page A-6 for explanation).

Chlorophyll a and Water Clarity

As indicated by chlorophyll a, the mid-lake sampling locations were generally characterized by moderate quantities of suspended algae in the illuminated surface waters of the lake, averaging 2.8 µg/l but reaching a maximum of 5.2 µg/l in the summer survey. The water clarity was good, as indicated by a mean Secchi disc value of 4.4 m. Additional work carried out by the Harp Lake Cottagers Association under the Ministry's "Self-Help Programme" has revealed¹ somewhat higher chlorophyll a concentrations during the latter two weeks of August of 7.4 and 8.6 µg/l, a period when no sampling was being carried on by the Recreational Lakes Programme. The somewhat higher mean chlorophyll a concentrations of 3.7 µg/l in samples analyzed for the Self-Help Programme was accompanied by correspondingly slightly lower Secchi disc values (averaging 4.0 m). Despite differences in sampling schedules, results from the two programmes basically are in agreement.

¹ Robinson, G.W. 1973. Enrichment Status of Harp Lake, District Municipality of Muskoka, 1973. Ontario Ministry of the Environment report, Limnology and Toxicity Section, Water Resources Branch.

Lakes exhibit their symptoms of enrichment in several ways (see p.A- 6 for explanation of the relationships between nutrient enrichment, lake water clarity and abundance of suspended algae). A curve relating chlorophyll a and Secchi disc values was derived by staff of the Ministry of the Environment and illustrates the status of Harp Lake relative to other well-known Ontario Lakes (Figure 16 ; see also p.A- 6). Based on chlorophyll a and Secchi disc data collected during the ice-free period of 1973, Harp Lake demonstrated a low to moderate degree of enrichment. Cottagers should ensure that seepage of nutrients to the lake from waste disposal facilities (thereby stimulating additional growths of suspended algae) does not occur.

Aquatic Plants in Shoreline Areas

Aquatic plant growth in shoreline areas of Harp Lake was very sparse and should not interfere with recreational activities on the lake. In areas of prominent plant growth, eight different species were collected (Table 2). Some of the plants could only be identified to genus because they lacked the fruiting and flowering structures necessary for complete identification. Figure 2 outlines the location and extent of the plant growth and lists the plants found in each area. While this figure shows the distribution and total density of the plants, the density or dominance of any particular plant type was not determined.

Future Considerations

It is expected that further work will be done in 1974 to study in more detail some of the factors leading to the translocation of bacteria and nutrients through the soil to the lake during rainfall. In this regard, an attempt will be made to set up controlled inputs of "artificial rainwater" (lake water pumped through conventional irrigation sprinkler systems) to a cottaged site containing a septic tank-tile bed system and to a similar but undeveloped site on Harp Lake.

The Private Waste and Water Management Branch will carry out their inspections of waste disposal systems on the lake during 1974 under the guidelines of the Cottage Pollution Control Programme. Cottagers are urged to comply with those remedial measures advised by Ministry staff carrying out the inspections so that any faulty systems can be corrected.

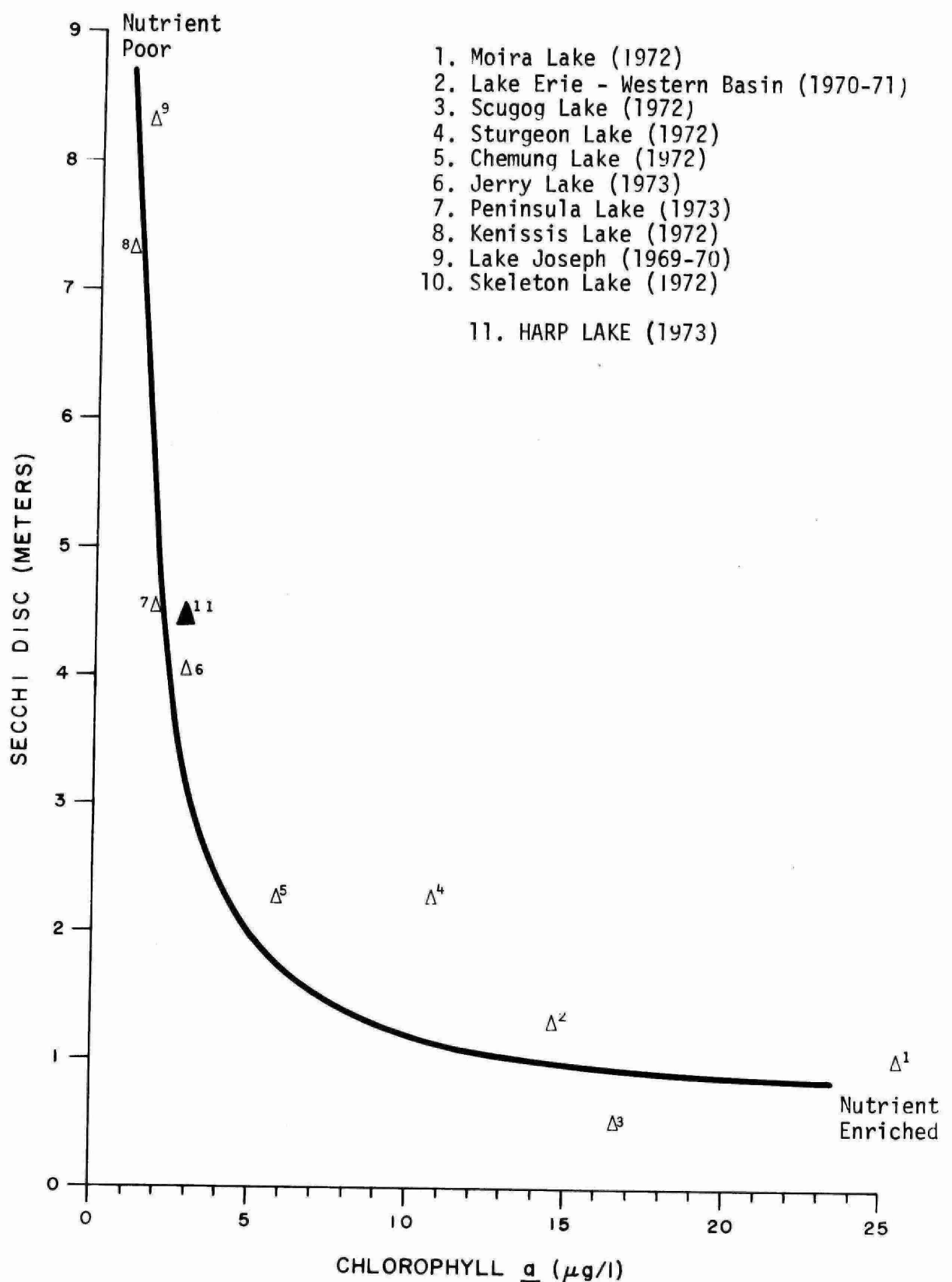


Figure 15: The mean of chlorophyll a and Secchi disc measurements in Harp Lake relative to a curve describing the chlorophyll a - Secchi disc relationship in many Ontario lakes. Ten other well-known lakes are included for comparison with Harp Lake.

Table 2: A list of the aquatic plants found in Harp Lake and the number of areas in which each plant type occurred. For convenience, the plants are divided into two categories: (a) submergent - aquatic weeds which live, for the most part, underwater and (b) emergent - aquatic weeds which produce floating or aerial leaves.

Scientific Name (genus species)	Common Name	Distribution (number of areas)
a) SUBMERGENT		
<u>Isoetes sp.</u>	quillwort	3
<u>Potamogeton natans</u>	floating-leaf pondweed	3
<u>Fontinalis sp.</u>	water moss	1
b) EMERGENT		
<u>Nuphar sp.</u>	yellow waterlily	3
<u>Nymphaea sp.</u>	white waterlily	2
<u>Pontederia cordata</u>	pickerelweed	4
<u>Sagittaria sp.</u>	arrowhead	2
<u>Dulichium arundinaceum</u>	three-way sedge	1

INFORMATION OF GENERAL INTEREST TO COTTAGERS

MICROBIOLOGY OF WATER

For the sake of simplicity, the micro-organisms in water can be divided into two groups: the bacteria that thrive in the lake environment and make up the natural bacterial flora; and the disease causing micro-organisms, called pathogens, that have acquired the capacity to infect human tissues.

The "pathogens" are generally introduced to the aquatic environment by raw or inadequately treated sewage, although a few are found naturally in the soil. The presence of these bacteria does not change the appearance of the water but poses an immediate public health hazard if the water is used for drinking or swimming. The health hazard does not necessarily mean that the water user will contract serious waterborn infections such as typhoid fever, polio or hepatitis, but he may catch less serious infections of gastro-enteritis (sometimes called stomach flu), dysentery or diarrhea. Included in these minor afflictions are eye, ear and throat infections that swimmers encounter every year and the more insidious but seldom diagnosed, sub-clinical infections usually associated with several waterborn viruses. These viral infections leave a person not feeling well enough to enjoy holidaying although not bedridden. This type of microbial pollution can be remedied by preventing wastes from reaching the lake and water quality will return to satisfactory conditions within a relatively short time (approximately one year) since disease causing bacteria usually do not thrive in an aquatic environment.

The rest of the bacteria live and thrive within the lake environment. These organisms are the instruments of biodegradation. Any organic matter in the lake will be used as food by these organisms and will give rise, in turn to subsequent increases in their numbers. Natural organic matter as well as that from sewage, kitchen wastes, oil and gasoline are readily attacked by these lake bacteria. Unfortunately, biodegradation of the organic wastes by organisms uses correspondingly large amounts of the dissolved oxygen. If the organic matter content of the lake gets high enough, these bacteria will deplete the dissolved oxygen supply in the bottom waters and threaten the survival of many deep-water fish species.

RAINFALL AND BACTERIA

The "Rainfall Effect" referred to in the text, relates to a phenomenon that has been documented in previous surveys of the Recreational Lakes. Heavy precipitation has been shown to flush the land area around the lake and the subsequent runoff will carry available contaminants including sewage organisms as well as natural soil bacteria with it into the water.

Total coliforms, fecal coliforms and fecal streptococci, as well as other bacteria and viruses which inhabit human waste disposal systems, can be washed into the lake. In Precambrian areas where there is inadequate soil cover and in

fractured limestone areas where fissures in the rocks provide access to the lake, this phenomenon is particularly evident.

Melting snow provides the same transportation function for bacteria, especially in an agricultural area where manure spreading is carried out in the winter on top of the snow.

Previous data from sampling points situated 50 to 100 feet from shore indicate that contamination from shore generally shows up within 12 to 48 hours after a heavy rainfall.

WATER TREATMENT

Lake and river water is open to contamination by man, animals and birds (all of which can be carriers of disease); consequently, NO SURFACE WATER MAY BE CONSIDERED SAFE FOR HUMAN CONSUMPTION without prior treatment, including disinfection. Disinfection is especially critical if coliforms have been shown to be present.

Disinfection can be achieved by:

(a) Boiling

Boil the water for a minimum of five minutes to destroy the disease causing organisms.

(b) Chlorination using a household bleach containing 4 to 5½ percent available chlorine.

Eight drops of a household bleach solution should be mixed with one gallon of water and allowed to stand for 15 minutes before drinking.

(c) Continuous Chlorination

For continuous water disinfection, a small domestic hypochlorinator (sometimes coupled with activated charcoal filters) can be obtained from a local plumber or water equipment supplier.

(d) Well Water Treatment

Well water can be disinfected using a household bleach (assuming strength at 5 percent available chlorine) if the depth of water and diameter of the well are known.

CHLORINE BLEACH
Per 10 ft. Depth of Water

Diameter of Well Casing in Inches	One to Ten Coliforms	More Than Ten Coliforms
4	0.5 oz.	1 oz.
6	1 oz.	2 oz.
8	2 oz.	4 oz.
12	4 oz.	8 oz.
16	7 oz.	14 oz.
20	11 oz.	22 oz.
24	16 oz.	31 oz.
30	25 oz.	49 oz.
36	35 oz.	70 oz.

Allow about six hours of contact time before using the water.

Another bacteriological sample should be taken after one week of use.

Water Sources (spring, lake, well, etc.) should be inspected for possible contamination routes (surface soil, runoff following rain and seepage from domestic waste disposal sites). Attempts at disinfecting the water alone without removing the source of contamination will not supply bacteriologically safe water on a continuing basis.

There are several types of low cost filters (ceramic, paper, carbon, diatomaceous earth sometimes impregnated with silver, etc.) that can be easily installed on taps or in water lines. These may be useful to remove particles, if water is periodically turbid, and are usually very successful. Filters, however, do not disinfect water but may reduce bacterial numbers. For safety, chlorination of filtered water is recommended.

SEPTIC TANK INSTALLATIONS

In Ontario, provincial law requires under Part 7 of the Environment Protection Act that before you extend, alter, enlarge or establish any building where a sewage system will be used, a Certificate of Approval must be obtained from the Ministry of the Environment or its representatives. The local municipality or Health Unit may be delegated the authority to issue the Certificate of Approval. Any other pertinent information such as size, types and location of septic tanks and tile fields can also be obtained from the same authority.

(1) General Guidelines

A septic tank should not be closer than:

-50 feet to any well, lake, stream, pond, spring, river or reservoir

- 5 feet to any building
- 10 feet to any property boundary

The tile field should not be closer than:

- 100 feet to the nearest dug well
- 50 feet to a drilled well which has a casing to 25 feet below ground
- 25 feet to a building with a basement that has a floor below the level of the tile in the tile bed
- 10 feet to any other building
- 10 feet to a property boundary
- 50 feet to any lake, stream, pond, spring, river or reservoir

The ideal location for a tile field is in a well-drained, sandy loam soil remote from any wells or other drinking water sources. For the tile field to work satisfactorily, there should be at least 3 feet of soil between the bottom of the weeping tile trenches and the top of the groundwater table or bedrock.

Recognizing that private sewage systems are relatively inefficient where shallow and inappropriate soil conditions are present (e.g. Precambrian areas) the Ministry of the Environment is conducting research into alternate methods of private sewage disposal in unsewered areas; into the improvement of existing equipment and methods of design and operation for these systems; and into the development of better surveillance methods such as by the use of chemical, biological and radioactive tracers to detect the movement of pollutants through the soil mantle.

DYE TESTING OF SEPTIC TANK SYSTEMS

There is considerable interest among cottage owners to dye test their sewage systems; however, several problems are associated with dye testing. Dye would not be visible to the eye from a system that has a fairly direct connection to the lake. Thus, if a cottager dye-tested his system and no dye was visible in the lake, he would assume that his system is satisfactory, which might not be the case. A low concentration of dye is not visible and therefore expensive equipment such as a fluorometer is required. Only qualified people with adequate equipment are capable of assessing a sewage system by using dye. In any case, it is likely that some of the water from a septic tank will eventually reach the lake. The important question is whether all contaminants including nutrients have been removed before it reaches the lake. To answer this question special knowledge of the system, soil depth and composition, underground geology of the region and the shape and flow of the shifting water table are required. Therefore, we recommend that this type of study should be performed only by qualified professionals.

BOATING AND MARINA REGULATIONS

In order to help protect the lakes and rivers of Ontario from pollution, it is required by law that sewage (including garbage) from all pleasure craft, including houseboats, must be retained in suitable equipment. Equipment which is considered suitable by the Ministry of the Environment includes (1) retention devices with or without re-circulation which retain all toilet wastes for disposal ashore, and (2) incinerating devices which reduce all sewage to ash.

Equipment for storage of toilet wastes shall:

1. be non-portable
2. be constructed of structurally sound material
3. have adequate capacity for expected use
4. be properly installed, and
5. be equipped with the necessary pipes and fittings conveniently located for pump-out by shore-based facilities (although not specified, a pump-out deck fitting with 1½-inch diameter National Pipe Thread is commonly used).

An Ontario regulation requires that marinas and yacht clubs provide or arrange pump-out service for the customers and members who have toilet-equipped boats. In addition, all marinas and yacht clubs must provide litter containers that can be conveniently used by occupants of pleasure boats.

The following "Tips" may be of assistance to you in boating:

1. Motors should be in good mechanical condition and properly tuned.
2. When a tank for outboard motor testing is used, the contents should not be emptied into the water.
3. If the bilge is cleaned, the waste material must not be dumped into the water.
4. Fuel tanks must not be overfilled and space must be left for expansion if the fuel warms up.
5. Vent pipes should not be obstructed and fuel needs to be dispensed at a correct rate to prevent "blow-back".
6. Empty oil cans must be deposited in a leak-proof receptacle, and,
7. Slow down and save fuel.

EUTROPHICATION OR EXCESSIVE FERTILIZATION AND LAKE PROCESSES

In recent years, cottagers have become aware of the problems associated with nutrient enrichment of recreational lakes and have learned to recognize many of the symptoms characterizing nutrient enriched (eutrophic) lakes. It is important to realize that small to moderate amounts of aquatic plants and algae are necessary to maintain a balanced aquatic environment. They provide food and a suitable environment for the growth of aquatic invertebrate organisms which serve as food for fish. Shade from large aquatic plants helps to keep the lower water cool, which is essential to certain species of fish and also provides protection for young game and forage fish. Numerous aquatic plants are utilized for food and/or protection by many species of waterfowl. However, too much growth creates an imbalance in the natural plant and animal community particularly with respect to oxygen conditions, and some desirable forms of life such as sport fish are eliminated and unsightly algae scums can form. The lake will not be "dead" but rather abound with life which unfortunately is not considered aesthetically pleasing. This change to poor water quality becomes apparent after a period of years during which extra nutrients are added to the lake and return to the natural state may also take a number of years after the nutrient inputs are stopped.

Changes in water quality with depth are a very important characteristic of the lake. Water temperatures are uniform throughout the lake in the early spring and winds generally keep the entire volume well mixed. Shallow lakes may remain well mixed all summer so that water quality will be the same throughout. On the other hand, in deep lakes, the surface waters warm up during late spring and early summer and float on the cooler more dense water below. The difference in density offers a resistance to mixing by wind action and many lakes do not become fully mixed again until the surface waters cool down in the fall. The bottom water receives no oxygen from the atmosphere during this unmixed period and the dissolved oxygen supply may be all used up by bacteria as they decompose organic matter. Cold water fish, such as trout, will have to move to the warm surface waters to get oxygen and because of the high water temperatures they will not thrive, so that the species will probably die out (see Figure next page).

Low oxygen conditions in the bottom waters are not necessarily an indication of pollution but excessive aquatic plant and algae growth and subsequent decomposition in the bottom waters can aggravate the condition and in some cases result in zero oxygen levels in lakes which had previously held some oxygen in the bottom waters all summer. Although plant nutrients normally accumulate in the bottom waters of the lakes, they do so to a much greater extent if there is no oxygen present. These nutrients become available for algae in the surface waters when the lake mixes in the fall and dense algae growths can result.

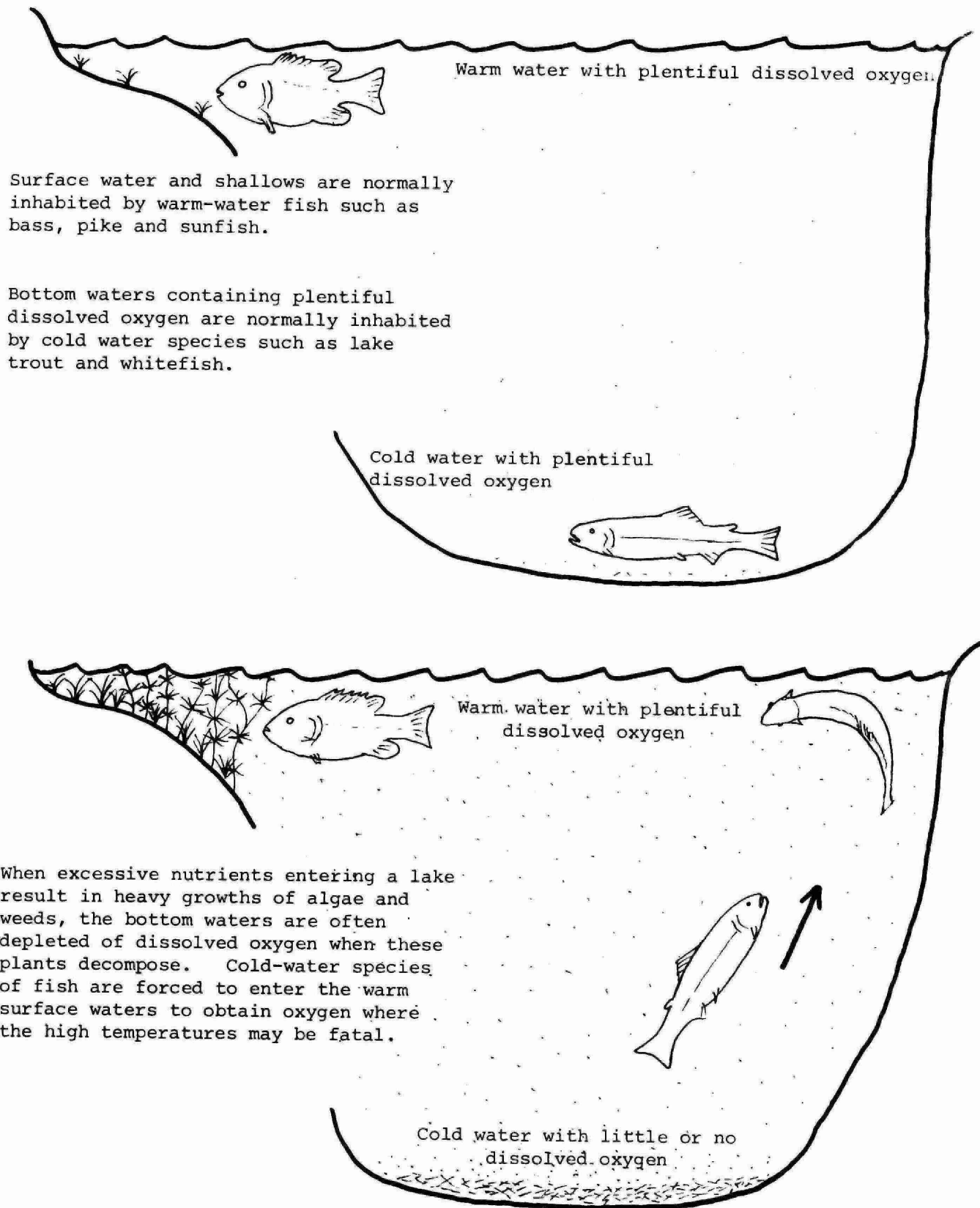


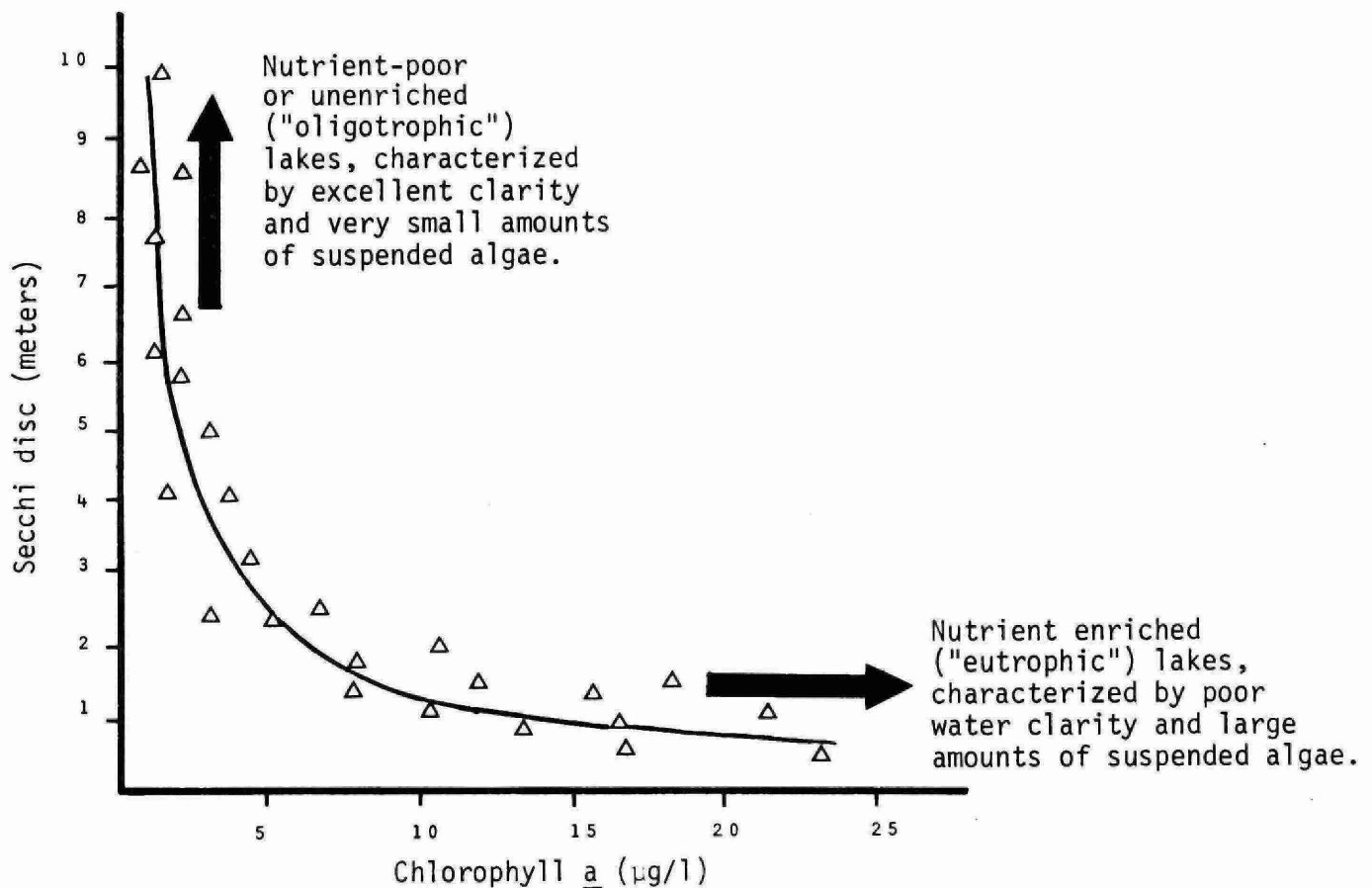
FIGURE A-1: DECOMPOSITION OF PLANT MATTER AT THE LAKE BOTTOM CAN LEAD TO DEATH OF DEEP-WATER FISH SPECIES.

Consequently, lakes which have no oxygen in the bottom water during the summer are more prone to having algae problems and are more vulnerable to nutrient inputs than lakes which retain some oxygen.

Like humans, aquatic plants and algae require a balanced "diet" for growth. Other special requirements including those for light and temperature are specific for certain algae and plants. Chemical elements such as nitrogen, phosphorus, carbon, and several others are required and must be in forms which are available for uptake by plants and algae. Growth of algae can be limited by a scarcity of any single "critical" nutrient. Nitrogen and phosphorus are usually considered "critical" nutrients because they are most often in scarce supply in natural waters, particularly in lakes in the Precambrian area of the province. Phosphorus, especially is necessary for the processes of photosynthesis and cell division. Nitrogen and phosphorus are generally required in the nitrate-N (or ammonia-N) and phosphate forms and are present in natural land runoff and precipitation. Human and livestock wastes are a very significant source of these and other nutrients for lakes in urban and agricultural areas. It is extremely important that cottage waste disposal systems function so that seepage of nutrients to the lake does not occur since the changes in water quality brought about by excessive inputs of nutrients to lakes are usually evidenced by excessive growths of algae and aquatic plants.

The large amounts of suspended algae which materialize from excessive inputs of nutrients, result in turbid water of poor clarity or transparency. On the other hand, lakes with only small, natural inputs of nutrients and correspondingly low nutrient concentrations (characteristically large and deep lakes) most often support very small amounts of suspended algae and consequently, are clear-water lakes. An indication of the degree of enrichment of lakes can therefore be gained by measuring the density of suspended algae (as indicated by the chlorophyll a concentration - the green pigment in most plants and algae) and water clarity (measured with a Secchi disc). In this regard, staff of the Ministry of the Environment have been collecting chlorophyll a and water clarity data from several lakes in Ontario and have developed a graphical relationship between these parameters which is being used by cottagers to further their understanding of the processes and consequences of nutrient enrichment of Precambrian lakes. The figure on the next page illustrates the above-mentioned relationship.

In the absence of excessive coloured matter (eg. drainage from marshlands), lakes which are very low in nutrients are generally characterized by small amounts of suspended algae (i.e. chlorophyll a) and are clear-water lakes with high Secchi disc values. Such lakes, with chlorophyll a and Secchi disc values lying in the upper left-hand area of the graph are unenriched or nutrient poor ("oligotrophic") in status and do not suffer from the problems associated with excessive inputs of nutrients. In contrast, lakes with high chlorophyll a concentrations and poor clarity are positioned in the lower right-hand area of the graph and are enriched ("eutrophic"). These lakes usually exhibit symptoms of excessive nutrient enrichment including water turbidity owing to large amounts of suspended algae which may float to the surface and accumulate in sheltered areas around docks and bays.



Measurements of suspended algal density (chlorophyll *a*) and water clarity are especially valuable if carried out over several years. Year to year positional changes on the graph can then be assessed to determine whether or not changes in lake water quality are materializing so that remedial measures can be implemented before conditions become critical.

CONTROL OF AQUATIC PLANTS AND ALGAE

Usually aquatic weed growths are heaviest in shallow shoreline areas where adequate light and nutrient conditions prevail.

Extensive aquatic plant and algal growths sometimes interfere with boating and swimming and ultimately diminish shoreline property values.

Control of aquatic plants may be achieved by either chemical or mechanical means. Chemical methods of control are currently the most practical, considering the ease with which they are applied. However, the herbicides and algicides currently available generally provide control for only a single season. It is important to ensure that an algicide or herbicide which kills the plants causing the nuisance, does not affect fish or other aquatic plants. Chemical control in the province is regulated by the Ministry of the Environment and a permit must be granted prior to any operation. Simple raking and chain dragging operations to control submergent species have been successfully employed in a number of situations; however, the plants soon re-establish themselves. Removal of weeds by underwater mowing techniques is certainly the most attractive method of control and is currently being evaluated in Chemung Lake near Peterborough. Guidelines and summaries of control methods, and applications for permits are available from the Pesticides Control Section, Pollution Control Branch, Ministry of the Environment, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5.

PHOSPHORUS AND DETERGENTS

Scientists have recognized that phosphorus is the key nutrient in stimulating algal growth in lakes and streams.

In past years, approximately 50 percent of the phosphorus contributed by municipal sewage was added by detergents. Federal regulations reduced the phosphate content (as P_2O_5) in laundry detergents from approximately 50 percent to 20 percent on August 1, 1970 and to 5 percent on January 1, 1973.

It should be recognized that automatic dishwashing compounds were not subject to the government regulations and that surprisingly high numbers of automatic dishwashers are present in resort areas (a questionnaire indicated that about 30 percent of the cottages in the Muskoka lakes have automatic dishwashers). Cottagers utilizing such conveniences may be contributing significant amounts of phosphorus to recreational lakes because automatic dishwashing compounds are characteristically high in phosphorus. Indeed, in most of Ontario's vacation land, the source of domestic water is soft enough to allow the exclusive use of liquid dishwashing compounds, soap and soap-flakes which are, in general, relatively low in phosphorus.

ONTARIO'S PHOSPHORUS REMOVAL PROGRAMME

By 1975, the Government of Ontario expects to have controls in operation at more than 200 municipal wastewater treatment plants across the province serving some 4.7 million persons. This represents about 90 percent of the population serviced by sewers. The programme is in response to the International Joint Commission recommendations as embodied in the Great Lakes Water Quality Agreement and studies carried out by the Ministry of the Environment on inland recreational waters which showed phosphorus to be a major factor influencing eutrophication. Specifically, the programme makes provision for nutrient control in the Upper and Lower Great Lakes, the Ottawa River system and in prime recreational waters where the need is demonstrated or where emphasis is placed upon prevention of localized, accelerated eutrophication.

Phosphorus removal facilities became operational at wastewater treatment plants on December 31, 1973, in the most critically affected areas of the province, including all the plants in the Lake Erie drainage basin and the inland recreational areas. The operational date for plants discharging to waters deemed to be in less critical condition, which includes plants larger than one million gallons per day (1 mgd) discharging to Lake Ontario and to the Ottawa River system, is December 31, 1975. The 1973 phase of the programme involved 113 plants, of which 48 are in prime recreational areas. An additional 53 new plants, each with phosphorus removal, are now under development, 23 of which are located in recreational areas. The capacities of these plants range from 0.04 to 24.0 mgd, serving an estimated population of 1,600,000 persons.

The 1975 phase will bring into operation another 54 plants ranging in size from 0.3 to 180 mgd serving an additional 3,100,00 persons. Treatment facilities utilizing the Lower Great Lakes must meet effluent guidelines of less than 1.0 milligram per litre of total phosphorus in their final effluent. Facilities utilizing the Upper Great Lakes, the Ottawa River Basin and certain areas of Georgian Bay where needs have been demonstrated must remove at least 80 percent of the phosphorus reaching their sewage treatment plants.

CONTROL OF BITING INSECTS

Mosquitoes and blackflies often interfere with the enjoyment of recreational facilities at the lake-side vacation property. Pesticidal spraying or fogging in the vicinity of cottages produces extremely temporary benefits and usually do not justify the hazard involved in contaminating the nearby water. Eradication of biting fly populations is not possible under any circumstances and significant control is rarely achieved in the absence of large-scale abatement programs involving substantial funds and trained personnel. Limited use of approved larvicides in small areas of swamp or in rain pools close to residences on private property may be undertaken by individual landowners, but permits are necessary wherever treated waters may contaminate adjacent streams or lakes. The use of repellents and light traps is encouraged as are attempts to reduce mosquito larval habitat by improving land drainage. Applications for permits to apply insecticides as well as technical advice can be obtained from the Ministry of the Environment, Pesticides Control Service, 3rd Floor, 1 St. Clair Avenue West, Toronto, Ontario.